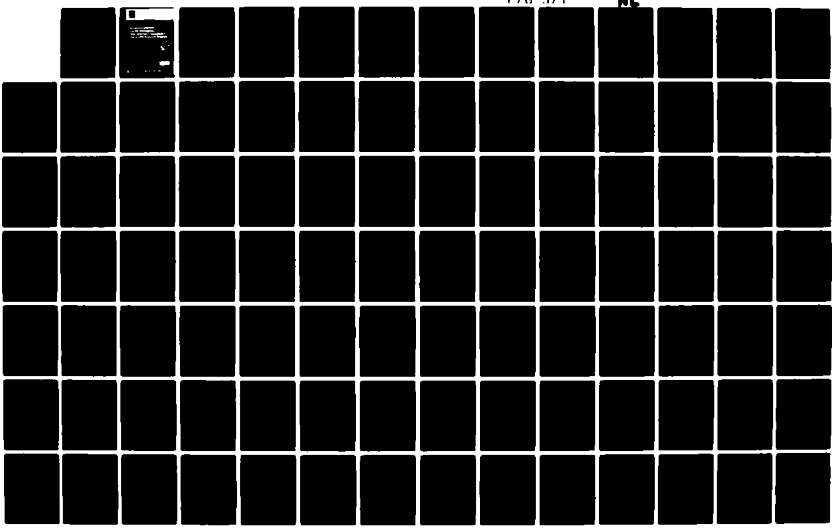

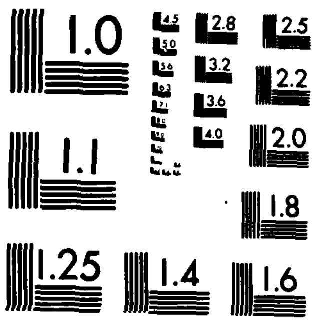

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COMMITTEE ON MARINE STRUCTURES

Of The

Marine Board
Commission on Engineering and Technical Systems
National Research Council

The Committee on Marine Structures provides technical advice to the Ship Structure Committee on design and fabrication of marine structures and on materials used in their construction. The advisory program comprises research projects with short, intermediate, and long-range goals. The members of the committee are:

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Prof. A. H.-S. Ang, (82), University of Illinois, Urbana, IL
Dr. K. A. Blenkarn, (84), Amoco Production Co., Tulsa, OK
Mrs. Margaret Ochi, (85), Gainesville, FL
Mr. D. Price, (84), National Ocean and Atmospheric Administration, Rockville, MD
Mr. D. A. Sarno, (83), ARMCO Inc., Middletown, OH
Mr. J. E. Steele, (83), Quakertown, PA
Mr. R. W. Rumke, Executive Secretary, Committee on Marine Structures

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Prof. R. G. Davis, (84), Texas A&M University, Galveston, TX
Mr. J. P. Fischer, (85), American Steamship Company, Buffalo, NY
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Dr. Nicholas Zettlemoyer, Exxon Production Research Company, Houston, TX

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Review and

Recommendations For the Interagency Ship Structure Committee's Fiscal 1984 Research Program

Committee on Marine Structures
Marine Board
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1983

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

****

This report was prepared for the interagency Ship Structure Committee, consisting of representatives from the Military Sealift Command, the U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, the American Bureau of Shipping, and the Minerals Management Service, and is submitted to the Commandant, U.S. Coast Guard, under provisions of Contract DOT-CG-23-81-C-20044 between the National Academy of Sciences and the Commandant, U.S. Coast Guard, acting for the Ship Structure Committee.

****

SHIP STRUCTURE COMMITTEE

The SHIP STRUCTURE COMMITTEE is constituted to prosecute a research program to improve the hull structures of ships and other marine structures by an extension of knowledge pertaining to design, materials and methods of construction.

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SHIP STRUCTURE SUBCOMMITTEE

The SHIP STRUCTURE SUBCOMMITTEE acts for the Ship Structure Committee on technical matters by providing technical coordination for the determination of goals and objectives of the program, and by evaluating and interpreting the results in terms of structural design, construction and operation.

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* Members of Executive Group

CONTENTS

ABSTRACT

The Committee on Marine Structures (CMS) of the Marine Board of the National Research Council provides technical services covering program recommendations, proposal evaluations, and project advice to the interagency Ship Structure Committee (SSC), composed of representatives from the the Military Sealift Command, U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, the American Bureau of Shipping, and the Minerals Management Service. This arrangement requires continuing interaction among the CMS, the SSC, the contracting agency, and the project investigators to assure an effective program to improve marine structures through an extension of knowledge of materials, fabrication methods, static and dynamic loading and response, and methods of analysis and design. This report contains the CMS' recommended research program for five years, FY 1983-1987, with nine specific prospectuses for FY 1984. Also included are two prospectuses for international collaboration and a brief review of eighteen active and seven recently completed projects.

INTRODUCTION

Organizational and Administrative Matters

Establishment of Committees

Since 1946, the National Research Council's Committee on Marine Structures (CMS) and its predecessors have been rendering technical services to the interagency Ship Structure Committee (SSC) in developing a continuing research program, sponsored by the SSC and funded collectively by its member agencies, to determine how marine structures can be improved for greater safety and better performance without adverse economic effect.

The SSC was established in 1946 upon recommendation of a Board of Investigation, convened by order of the Secretary of the Navy, to inquire into the design and methods of construction of welded steel merchant vessels. As that investigation was brought to a close, several unfinished studies and a list of worthy items for future investigation remained. The Board of Investigation recommended that a continuing organization be established to formulate and coordinate research in matters pertaining to ship structure. Figure 1 shows the relationship of the various organizational entities involved in the work of the SSC.

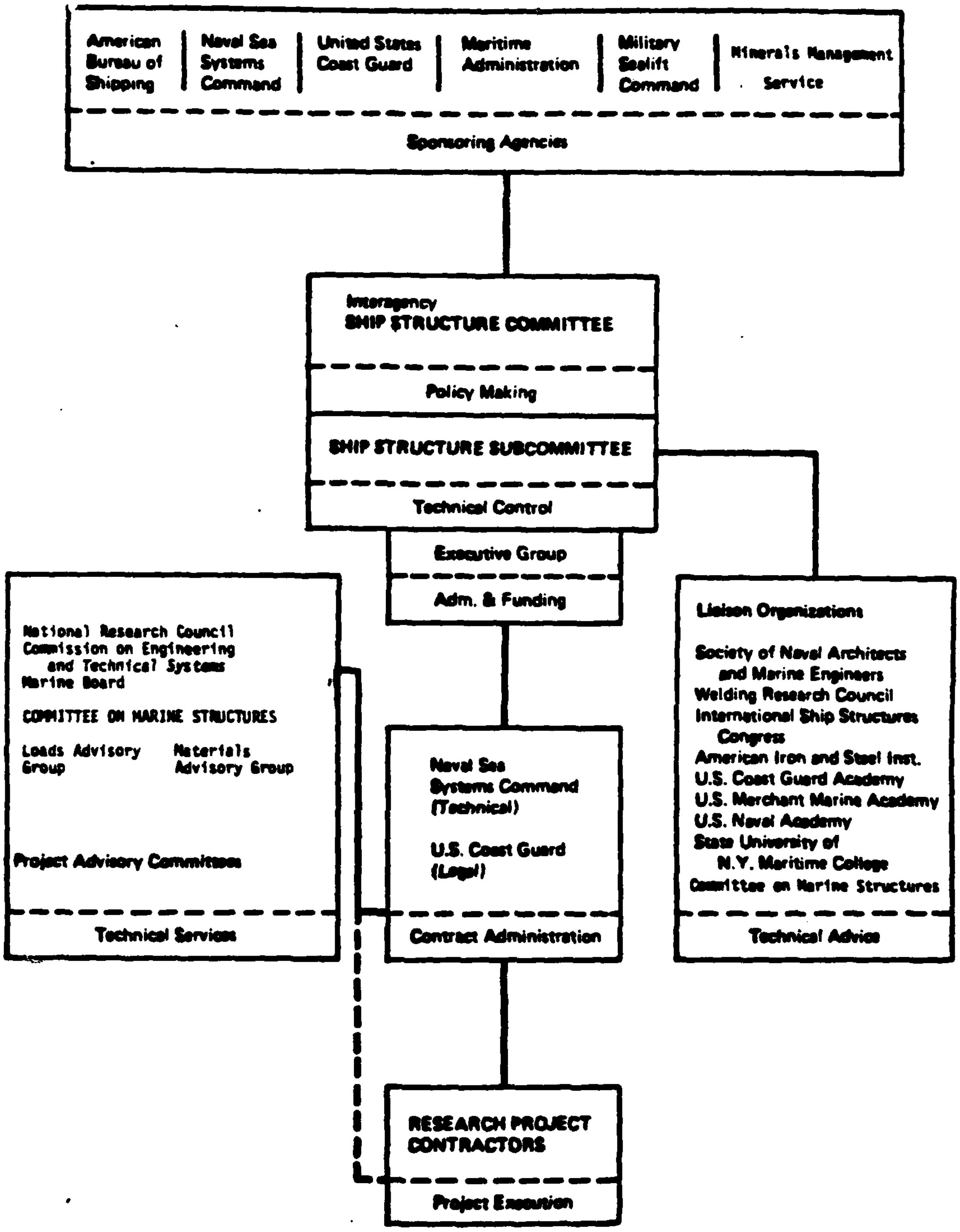


FIGURE 1. SHIP STRUCTURE COMMITTEE ORGANIZATION CHART

Committee Composition and Responsibilities

The SSC is composed of one senior official from each of the following organizations: the Military Sealift Command, the U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, the American Bureau of Shipping, and the Minerals Management Service.

The SSC formulates policy, approves program plans, and provides financial support through its member agencies for the research program.

A maximum of four representatives from different divisions within each agency meet periodically as a Ship Structure Subcommittee (SSSC) to assure achievement of program goals and to evaluate the results of research projects in terms of structural design, construction, and operation.

Members of the CMS and its advisory groups are selected from academic, governmental, and industrial sources for their competence and experience in relevant areas. The members serve as individuals contributing personal knowledge and judgment, and not as representatives of organizations where they are employed or with which they are associated. The CMS' responsibilities to the SSC are to assist in setting technical objectives, define research projects, recommend research priorities, evaluate proposals, review the active projects including progress and final reports, and prepare summaries of related research work.

Research Program Development

Each organization represented on the SSC presents its current annual research needs and suggestions for research projects.

Beginning in 1976, an annual joint meeting of members of the CMS, the Hull Structure Committee of the Society of Naval Architects and Marine Engineers, and the SSSC was initiated to review these suggestions. At a following one-day meeting, the CMS alone carefully reviews these suggestions, those generated within the CMS and its advisory groups, those not funded from the prior year, and those obtained from any other sources for applicability to the SSC research program in terms of needs, immediacy, program continuity, and likelihood of successful and meaningful completion.

At the fall meeting of the SSC, the CMS presents its preliminary reactions to all of the suggestions. The member agency representatives then express their agency's preferences and indicate where they feel the emphasis of the ongoing research program should be placed. The results of this meeting are compiled as lists of suggested areas for the advisory groups to assess.

Project Development

The advisory groups convene to review in detail the status of the ongoing projects and the CMS suggestions for new work. Members draft prospectuses either individually or in small task forces. These prospectuses contain a short statement on the background and basis of need, an outline of the work required to develop the desired information, and a list of technical specifications and special provisions.

A second meeting is convened for each advisory group to review the draft prospectuses place them in a priority order, and develop the five-year research program in their respective areas of competence. Each group also reviews and puts in final form drafts of

the status and progress reports on projects and prepares *active*, pending, or completed during the past year and prepares a brief overview of the technical scope of their portion of the program.

The advisory groups send all of these documents to the CMS which completes all work and ranks projects for the preparation of the annual report.

The SSC determines which projects will be supported. Requests for Proposals (RFP) are then prepared and issued through the cooperative effort of the Naval Sea Systems Command, which provides technical contract administrative support services, and the U.S. Coast Guard, which handles the actual business of contracting. The RFPs are sent to research laboratories, universities, shipyards, and other organizations and are advertised in the Commerce Business Daily.

Proposal Evaluation Procedure

Organizations interested in doing the work adverstised submit proposals and cost estimates. The USCG contracting office removes the cost estimates and transmits the technical data in the proposal to the CMS for evaluation and review.

The CMS chairman selects an *ad hoc* proposal evaluation committee that generally consists of the chairmen of the CMS and the pertinent advisory group and two or three other members from either the advisory group or the CMS. This committee evaluates the proposals for their analysis of the problem, the proposed solution, the assessment of the scope of the effort, and the adequacy of the organization and personnel.

After the evaluation, the committee judges the technical merit of the proposals, ranks them, and comments on any shortcomings, which are forwarded to the USCG in the form of a meeting summary. The USCG contracting officer combines the technical evaluation with the cost data and forwards them to the SSC. The SSC considers the proposals together with the technical evaluation and costs estimates and sends its recommendations to the contracting officer, who, following routine procurement practices, then awards a contract.

Dissemination of SSC Research Information

The contractors prepare reports upon completion of a coherent series of tests or discrete unit of work, upon a major change of course in a project, upon a significant discovery, or upon termination of a project. Normally, the SCC publishes such reports to fulfill its mission of disseminating the results of research pertaining to marine structures. In addition, the SSC encourages the investigators to prepare papers for presentation before professional society meetings or for submission to technical journals.

To foster the use of the published information, the SSC distributes the reports to individuals and agencies associated with and interested in its work. The availability of these reports is also noted by the National Technical Information Service (NTIS) and in various marine and naval architecture journals. Further, over one hundred leaders and officers of the marine structure community receive personal copies directly from the SSC Chairman, to further this new information in the working design industry.

Annual Report Summary

This report, the latest in the series of annual reports, covers the research activities for FY 1983, sets forth recommendations for the SSC's FY 1984 research program, and outlines a five-year research planning program.

Five-Year Research Program Development

Although the five-year research program plan serves as a useful working document for administering and guiding the near-term research efforts of the SSC, there is a need for longer range research plans to help ensure that current efforts apply to long-term goals. The most recent activity in this regard was project SR-1296, "Long-Range Research Plan Review." The investigators, MacCutcheon, Oakley, and Stout, state:

> This study constitutes a look at the long-range needs and opportunities to improve ship structures through research and development initiated between now and A.D. 2000. The aim of this study is to provide the Ship Structure Committee (SSC) and its associated planning groups and staff with guidance that will be useful in formulating five year and annual plans for research and development programs and projects.
>
> The investigators on this study recognize the need for a pattern to pull together global trends, system needs, technological opportunities, the technical shortfalls which had to merge in defining the desirable research and development for the SSC.

The principal conclusion of this study was the ranking, by importance, of the work parcels of mutually supporting sets of research and development tasks shown in Table I.

TABLE I - WORK PARCELS RANKED BY IMPORTANCE

1 Fitness for Service Criteria
2 Weld Inspection and Repair Standards
3 Designing for Inspectability and Maintainability
4 Optimization Among Design Criteria
5 Design Details to Aid Production
6 Effect of Maintenance on Reliability
7 Ice Loading Criteria
8 Review of Industrial Engineering Applications
9 Ductile Fracture Mechanics for Ship Steels
10 Hull Girder Collapse, Analysis of Torsion and Torsion-Buckling Modes
11 Vibrations Prediction Modeling-Techniques Improvement
12 Viability of Concrete Hulls
13 Joining Copper-Nickel to Steel
14 Impact on Structural Elements, Analysis and Criteria
15 Hull Girder Failure, Analysis of Fracture Mode
16 Shakedown Analysis of Hull Girders
17 Wave Data for Design
18 Crack Arrest in Metals
19 Shipyard Production Control
20 Rational Ship Design
21 Analytical Study of Hull Pressures Induced by Intermittent Propeller Cavitation
22 Designing for Corrosion
23 Vibration Studies Scheduling in the Design Cycle
24 Finite-Element Methods (FEM) Computer Program Survey
25 Directional Sea Spectra
26 Superimposing Design Loads
27 Guidelines for Scheduled Inspection and Maintenance
28 Hull Girder Collapse, Buckling and Plastic Modes
29 Wave-Induced Springing Response
30 Casualty Reporting
31 Added Mass of Locally Vibrating Structure
32 CAD/CAM Data Base Formats
33 Correlation of Calculated and Measured Propeller Blade Pressures
34 Hull Girder Deflection Criteria
35 Outfit Design System Specification
36 Welding Robots and Adaptive Controls
37 Transverse-Strength Analysis
38 Nondestructive On-Line Inspection Technique
39 Design-for-Production Manual
40 Cargo/Structure Interaction
41 Validation of Methods for Predicting Higher Mode Frequencies
42 Analytical Study of Wake, Hull Shape and Propeller-Induced Forces
43 Effect of Sheathing on Skin Friction
44 Collisions and Groundings
45 Local Response to Liquid Cargo Sloshing Impact
46 Combinmation of Low and High Frequency Loads
47 Ship Collisions, Analysis of Hydrodynamic Forces
48 Computer Program Clearing House

TABLE I - WORK PARCELS RANKED BY IMPORTANCE (Continued)

49 Future Needs for Computer-Aided Design (CAD) Methods
50 Experimental Determination of a Family of S-N Curves for Typical Ship's Structural Details
51 Slamming and Bow Flare Impact, Local Response
52 Predicting Wave-Impact Loads
53 Ultrasonic Inspection
54 Structural Failure
55 Slamming and Bow Flare Impact, Hull Girder Response
56 Local Response to Green Water on Deck
57 Combined Bending and Torsion Loads on Ships
58 Improved Welding Methods and Consumables
59 Ice Loads on Ships and Platforms
60 Ship Collisions, Hull Structural Elements, Model Test Program
61 Method for Predicting Loads Induced by Large Non-Linear Head Seas
62 Method for Predicting Moored-Vessel Motions and Loads
63 Structural Performance, Monitoring in Service
64 Predicting Propeller-Induced Forces
65 Fatigue Parameter Evaluation
66 Ship Grounding Loads, Analysis and Experiment
67 Designing Against Fatigue
68 Guidelines for Repair of Marine Concrete Structures
69 Ship Vibration Response, Full-Scale Measurements
70 Reliability of Structure
71 Designing to Minimize Green Water Loads
72 Study of Wake Harmonics Using Instrumented Propeller
73 Study of Wake Harmonics, Model and Full-Scale Measurements
74 Designing Concrete Structure, Methods and Criteria
75 Designing Artic Submarine Structure, Methods and Criteria
76 Hull Girder Response to Green Water on Deck
77 Corrosion in Concrete and Its Inhibition
78 Develop High Strength-to-Weight Concrete
79 Reliability Analysis
80 Damage Assessment in Concrete
81 Ship Collisions, Large-Scale Experiments
82 Evaluation of Alternative Reinforcements in Concrete
83 Fatigue in Marine Concrete Structures
84 Static Torsion of Ship's Hull Girder
85 Reliability of Structures and Elements

Source: Ship Structure Committee Long-Range Plan: Guidelines for Program Development by MacCutcheon, E. M., et al, Ship Structure Committee Report, SSC-316, 1982.

Further, the SR-1296 investigators state:

> In making the foregoing recommendations we have assumed that the SSC will continue two important procedures as it uses the long-range guidelines in choosing its programs and projects. First, it should continue emphasis on literature searches in advance of experimental work. And second, in the frequent cases for which the nature of the experiments is in doubt, it should continue the practice of conducting exploratory projects. These two traditional SSC practices will continue the sound approach to program planning and the efficiency of the SSC R&D efforts.

In reviewing the work parcels identified in SR-1296, the CMS found that 56 work parcels are either in the five-year research program plan for near-term undertaking or will eventually appear in a deferred time interval.

Also, the CMS noted that the remaining 29 of the 85 parcels listed either would not fall under the SSC terms of reference (to prosecute a research program to improve the hull structure of ships and other marine structures by an extension of knowledge pertaining to design, materials and methology of construction), were completed, or were being undertaken by other agencies or organizations. Of these 29, No. 8, 19, 36, 38, 49, and 53, were considered to come under the umbrella of the MarAd-SNAME-Navy ship productivity programs; No. 13 is being done by a SNAME panel; No. 21, 32, and 35 are presently being done by the Navy; No. 29 is being followed by the USCG; No. 58 falls under the Welding Research Council's purview; No. 33, 43, 48, 72, and 73 are outside the SSC's area of interest; and No. 24, 34, 40, and 75 are now complete. Finally, Nos. 12, 68, 74, 77, 78, 80, 82, and 83 deal with concrete, and the SR-1296 investigators state:

> Because concrete ships would consume on the the order of 70 percent added fuel due to their greater total weight and save only 10 percent of the steel weight, of comparably-productive all-steel counterparts, the use of concrete for transportation systems is unlikely. In contrast, the resistance to corrosion may commend concrete as a suitable material for weight-insensitive platforms.

In another vein the investigators of SR-1296 also made the following statements:

> Traditionally the Ship Structure Committee has focused on ships and built its professional and scientific technical constituency to support ship problems. Soil mechanics and quasi-rigidity are examples of technical domains, important for bottom-mounted structures, which have not been addressed in the ship program. Inasmuch as the Ship Structure Committee has only recently received a clear mandate for offshore platforms, there is little in its present or proposed programs bearing on the problems of bottom-mounted or floating platforms. The LRRP study, which was commenced before the decision was made to include bottom-mounted platforms in the SSC research program, reflects this dirth of content.

> Recommendation: We recommend that the Ship Structure Committee formulate a policy regarding its involvement with offshore platforms. Because the SSC appears to be gradually moving into this area, the technical scope of planning should be increased to address problems associated with bottom-mounted platforms.

The members of the CMS concur with this, since over the past thirty years or so, there has been increasing development of various types of offshore structures. These structures have largely been fixed platforms for petroleum drilling and production, and mobile offshore drilling units. They have also been single-point mooring buoys, mining structures for sulphur and other minerals, offshore loading and unloading stations, oil storage units, and experimental versions of manganese nodule mining vessels and ocean thermal energy conversion plants.

All of these offshore structures have a good deal in common with ships. They all float or are floated for at least a portion of their existence. They all are subject to wave action and must be structurally adequate to withstand the forces involved. Almost all are made primarily of steel, both medium strength and high strength. Almost all are assembled primarily by welding and are afflicted with the common problems of welded steel structures including fatigue, buckling, brittle fracture, lamellar tearing, and corrosion. They are usually subject to classification by the various classification societies and to regulation and inspection, for United States waters, by the U.S. Coast Guard or by the Minerals Management Service for fixed platforms.

There are also, of course, major differences between ships and these various types of offshore structures. One such difference is their relationship to wave forces. The offshore structures are generally fixed to stay in one spot and, therefore, receive a more frontal attack from the waves than do ships, which are relatively free to move with the wave action. In recognition of this difference, calculational procedures have evolved which predict the forces of waves on fixed structures, probability-based methods are used to estimate the size of the design wave as a function of duration of exposure, and risk is acknowledged by selecting some finite period, such as 100 years, for the determination of the wave size. In these areas, designers of offshore structures may have made more progress towards achieving the goal of "rational design" than have the designers of more conventional ships, who still use largely "traditional" methods in the actual design procedure.

Another major difference between ships and other offshore structures is the intimate relationship that many of the latter have with the soil of the ocean bottom. An understanding of this subject is fundamental to the design of fixed petroleum structures and of those mobile drilling units that are bottom supported, such as jack-ups and submersibles. Structures which are held in place by anchors, such as semi-submersible drilling platforms, mooring buoys, and OTEC plants, also require a knowledge of soil behavior.

Following with the SR-1296 recommendation and the broadened SSC research program, the current five-year plan now calls for a review of the research requirements for offshore structures and consideration of the SSC role in offshore research and development. This review must be based on an awareness of the large amount of past and present research work that various organizations around the world have undertaken on the general subject of offshore structures. Fixed oil platforms have received particular attention. This research is reported in various publications such as the annual proceedings of the Offshore Technology Conference. The review should mention areas where significant technical questions remain to be investigated and where the activities and interests of the SSC provide special expertise. The review might also acknowledge that a large portion of past SSC effort, particularly in the fields of materials and fabrication techniques, applies as directly to offshore structures as it does to ships. This would include:

SR-1270, Survey of Experience Using Reinforced Concrete in Floating Marine Structures

SR-1283, Performance of Underwater Weldments

SR-1287, Joint Occurrence of Environmental Disturbances

SR-1288, Fracture Control for Fixed Offshore Structures

SR-1299, Design-Inspection-Redundancy Symposium/Workshop

Currently, CMS developed two potential programs to the prospectus stage:

Coastal Offshore Meteorology, Worldwide

Coastal Offshore Soils, Worldwide

Finally, the Marine Board is also examining opportunities for strengthening the activities of the CMS in the offshore structures area.

Five-Year Research Program Plan

The five-year research planning program depicted in Table II builds on current activities and places them in perspective with contemplated work in various project areas during the next four years.

The program is classified under the following seven goal areas of the SSC:*

Advanced Concepts and Long-Range Planning

Loads Criteria

Response Criteria

Materials Criteria

Fabrication Techniques

Determination of Failure Criteria (Reliability)

Design Methods

* These goals were accepted and approved by the SSC in fiscal year 1972 directive that all their future research plans, beginning with fiscal year 1973 be based upon them.

CMS includes verification processes of the work in each of these areas to ensure that recommendations can be made on a sound technical basis. CMS intends that the research contribute to design methods, fabrication procedures, and materials for safer and more efficient marine structures. CMS also intends that the program be dynamic and flexible so that it can be modified and redirected to be responsive to changing circumstances.

TABLE II--COMMITTEE ON MARINE STRUCTURES RECOMMENDATIONS FOR AN SSC FIVE-YEAR RESEARCH PROGRAM

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
GOAL AREA: I - ADVANCED CONCEPTS AND LONG-RANGE PLANNING					
<u>Overall research planning studies</u>	Conduct CMS-SSSC-HSC joint meeting to present current efforts and planned research work on offshore structures.	Conduct CMS-SSSC-HSC joint meeting to present current efforts and planned research work on ice loads.	Conduct CMS-SSSC-HSC joint meeting to present current efforts and planned research work in computer applications.	Conduct CMS-SSSC-HSC joint meeting to present current efforts and planned research work on fatigue.	Conduct CMS-SSSC-HSC joint meeting to present current efforts and planned research work on vibration or on welding defects.
		Consider SSC role in offshore structural research and development.			
<u>Conduct technical symposia</u>	<u>Begin preparations for FY-1985 Symposium on Marine Structures for the Future.</u>	<u>Continue preparations for FY-1985 Symposium.</u>	<u>Conduct symposium.</u>	Consider topics for *FY-1988* symposium.	Continue preparations for *FY-1988* symposium.
	<u>Begin preparations for a Design--Inspection--Redundancy Symposium/Workshop for FY 1984. SR-1299</u>	<u>Conduct symposium. SR-1299</u>			
GOAL AREA: II - LOADS CRITERIA					
<u>Static/quasi static</u>			Develop prospectus to conduct data collection program for still-water bending moment.	Conduct still-water bending moment data collection program.	Continue data collection program. Review first-year results.

Key:
Underlined text refers to completed, active, and pending projects, and committee efforts.
(SR-0000) designation refers to projects described in the yellow pages of this report.

Open text refers to proposed projects and research efforts.
(84-00) refers to project recommendations described in the green pages of this report.

TABLE II (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
GOAL AREA: II - LOADS CRITERIA (Continued)					
Dynamic	Compile, review, & correlate model and full-scale liquid slosh data. Devise & conduct model tests with various fill depths, specific densities, geometrics, and excitations. (SR-1284)	Develop general-purpose curves and tables of dynamic loading data for use in design of liquid cargo tanks. (SR-1284)	Review SR-1284 data and determine if further research efforts are required.		
Wave-induced	Develop a model & background material to statistically estimate frequencies of joint occurrence of winds and waves. (SR-1287)				
	Develop detailed plan for full-scale slam instrumentation & wavemeter data collection on oceangoing ship, with due consideration for for follow-on model tests. (SR-1295)	Implement plans for full-scale slam instrumentation, and data collection on ocean-going ship (SR-1295)	Analyze data collected from full-scale test and compare them with theoretical results. (SR-1295)	Conduct model tests duplicating full-scale tests. Compare results with prototype and theory.	Examine total slamming program results to develop where additional work may be needed.
	Review SR-1281 results of the experience of vessels encountering extreme waves and determine if additional studies or data gathering is required.	Develop prospectus to pursue non-gaussian waves from a fluid mechanics point of view.			
	Formulate a hydrodynamic model for predicting ship motions and wave loads above and below the still-water line. (SR-1277)	Develop a motions and distributed loads computer program. (SR-1277)	Complete computer program and evaluate oblique sea efforts. (SR-1277)		

TABLE II (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
		GOAL AREA: II - LOADS CRITERIA (Continued)			
Wave-induced (Continued)		Compare full-scale M/V CORT pressure data for head and oblique seas. (84-9)	Accomplish model tests in oblique waves and perform model/model and model/full-scale comparisons.	Evaluate tests and data comparisons as an acceptable base for computer program verification.	
Collisions & groundings	Develop specifications for calculation aids for the assessment of damage, stability, and survivability of grounded vessels. (SR-1294)		Develop grounding loads & analysis logic for a computer program.	Develop grounding loads & analysis computer program.	Develop logic to incorporate dynamic loading. Expand grounding loads & analysis computer program with dynamic loading capacity.
Combined loads		Write prospectus for program to assess interrelationships and nonlinearity effects of various load conditions in different parts of ship structure.	Assess interrelationships and nonlinearity effects of various load conditions in different parts of ship structure.	Prepare design load profiles & recommend modifications to design criteria.	
			Consider need to develop procedure for predicting transverse plane motions and transverse and torsional loads.	Fabricate large-scale hull girder model and test to failure, measuring stresses and deformations and comparing with calculations.	Evaluate possibility of using ultimate strength in hull girder design roles.
			Develop a method to statistically estimate the combined wave-induced bending, vibration, and torsional loads necessary to perform structural failure analysis.		

TABLE II (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
		GOAL AREA: III - RESPONSE CRITERIA			
Vibrations	Organize vibration-related projects, such as full-scale data collection, model tests, developing added mass characteristics, verifying analytical procedures, into a planned program.	Correlate the proposed vibration-related projects program with the long-range planning document from SR-1296.			
		Prepare a program for developing and validating hull damping calculation procedures. (84-7)	Develop a method for calculating damping in flexible hulls.	Validate calculation method with full-scale tests.	
	Develop a vibration-control guide for ship operators. (SR-1293)	Review guide and develop method to update, expanJ, and provide a more comprehensive guide.	Continue developing guide elements. Review use of vibration-control guide and update.		
		Consider developing a *prospectus for a* vibration design guide.			
Stress-deformation analysis and prediction		Provide a state-of-the art review and basis for rationale for selecting strategies for performing and evaluating nonlinear analysis of marine structures under random loading. (84-8)			
		Develop electronic shipboard strain recorder. (84-1 Phase I)	Build, test, and validate prototype electronic strain recorder. (84-1 Phase II)		

TABLE I (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
		GOAL AREA: III - RESPONSE CRITERIA (Continued)			
Stress-deformation analysis and prediction (Continued)	Develop a generalized operations-oriented stress and motion monitoring system. (SR-1300)	Install and operate system on three different vessel types. (SR-1300)	Evaluate results and prepare final specifications for system. (SR-1300)		
Ice	Develop instrumentation for ice breaker hull load measurements and gather data. (SR-1291)	Analyze SR-1291 data.	Possibly collect a second year's data.		
			Refine load factors, compare ice strengthening scantlings resulting from this approach with existing criteria and reduce to a limited number of ice cases.	Develop response factors by applying analytic techniques to various hull configurations and ice loadings.	Generalize analytical model of ship-ice interaction to provide for high triaxial crushing strengths, high-strain rate, and irregular load distribution.
		GOAL AREA: IV - MATERIALS CRITERIA			
Fracture & fatigue control	Conduct fatigue tests on components and assemblies on which data are not available. (SR-1298)	Continue SR-1298.	Complete and review SR-1298.	Develop multiple-year program to evaluate effect of production deficiencies, such as weld flaws and fit up, on the performance of selected structural details in fatigue.	Implement fatigue program.
	Complete project developing procedure to measure shipboard strain rates. (SR-1285)	Confirm ship hull strain rates from existing full-scale data as suggested in the SR-1285 study. (84-5)	Consider effects of strain rates determined in 84-5 on fitness-for-service analysis.	Consider necessity of evaluating effect of worst-case scenarios.	Consider reviewing fracture-design criteria in light of strain-rate studies.

TABLE II (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
		GOAL AREA: IV - MATERIALS CRITERIA (Continued)			
Fracture & Fatigue Control (Continued)	Complete SR-1276 on assessing long-term corrosion fatigue data in the design of offshore structures and ships and develop a long-term test plan.	Review SR-1276 results and indicate research in needed areas.	Begin long-term corrosion fatigue tests.	Continue testing, interim analysis.	Continue testing, interim analysis.
		Initiate project to determine the amount of damage produced in ship structures by cyclic loading prior to occurrence of visible cracks. (84-2)	Continue with fracture toughness and crack-growth rate tests on pre-fatigued ship plate. (84-2)	Review 84-2 project results. If prior damage is detected, develop program for continued effort to quantify damage and service conditions where damage is important.	Implement research program.
	Critically review fracture-control plans for fixed offshore platforms which include material properties and designs for increased reliability in extreme marine environments. (SR-1288)	Review program and establish need for validation of elements of a fracture-control guide for fixed offshore structures.	Initiate specific projects.	Continue effort.	
	Study ship fracture mechanisms in light of today's knowledge of fracture mechanics. (SR-1290)	Examine potential courses for future research and continue evaluation of new fractures. (SR-1290)	Review SR-1290 results together with those techniques of NSRDC, Annapolis, MD.	Review safety analysis of ship structural details against fracture and fatigue failures. Develop reliability-based inspection and maintenance schedules to insure safety against brittle fracture.	Develop an overall fracture-control plan for ships that incorporate both fatigue and fracture behavior of fabricated ship details and a reliability analysis.

TABLE II (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
		GOAL AREA: IV - MATERIALS CRITERIA (Continued)			
Corrosion Control		Define data gathering requirements and methodologies for corrosion data bank. (84-4)	Complete program to define data gathering requirements for corrosion data bank. (84-4)	Implement ongoing program to gather corrosion data.	Continue program to gather *corrosion* data.
				Prepare program to develop statistical approach to corrosion prediction.	Contract and initiate program to develop statistical approach to corrosion prediction.
Materials applications					
Arctic materials		Review service experience on steels in non-marine, cold-weather applications to evaluate for potential marine use.	Review 84-3 and compare with NBS results on arctic materials research.	Undertake new material research relevant to arctic resource development based on 84-3.	Continue research.
Cu-Ni-clad steels	Follow SNAME HS-9 panel's project for the economic analysis and technical awareness of Cu-Ni clad steels.	Review HS-9 panel's results.	Consider program to augment the HS-9 work in this area, if warranted.	Initiate and carry out program.	Continue effort.
Effects of High Deposition Weld-Improved HAZ	Identify critical controls & compositions in the developments of improved weldments using high-deposition-rate processes and procedures. (SR-1256)	Conduct more detailed metallurgical examination of fourteen promising steel compositions. (SR-1256)	Complete metallurgical examination and recommend best composition to use for high-heat input welding. (SR-1256)	Produce full-scale heat of best composition and have different shipyards participate in testing program.	Provide an initial guide for use on high-deposition rate weld processes in ship construction.
		GOAL AREA: V - FABRICATION TECHNIQUES			
Underwater Welding	Examine performance of underwater and water-backed welds. (SR-1283)	Conduct necessary testing and evaluate program. (SR-1283)	Review project results.		

TABLE II (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
GOAL AREA: V - FABRICATION TECHNIQUES (Continued)					
Influence of weld defects on integrity of marine structures		Obtain a better understanding of the dependence of the integrity of marine structures on weld porosity. (84-6)	Determine influence of linear weld defects, including slag, on the basis of fracture mechanics requirements and NDI capabilities.	Determine influence of planar weld defects, on the basis of fracture mechanics requirements and NDI capabilities.	Continue studies, where necessary.
GOAL AREA: VI - DETERMINATION OF FAILURE CRITERIA (RELIABILITY)					
Failure modes & safety analysis	Complete assessment and analysis of major uncertainties in current ship hull design procedures. (SR-1280)	Review results relative to ongoing work on reliability of fixed and floating offshore platforms.			
In-service monitoring	Develop a guide to put forth a coherent philosophy for ship structural inspections. (SR-1289)	Review results relative to ongoing work on inspection of fixed and floating offshore platforms.			
Risk and reliability			Review the results and recommendations from the 1984 Design-Inspection-Redundancy Symposium/Workshop to develop prospectuses. (SR-1299)		
GOAL AREA: VII - DESIGN METHODS					
Design procedures	Examine SL-7 hatch-corner failure and document and compare experience with theoretical calculations. (SR 1297)	Review SR-1297 results.			

TABLE II (Continued)

Project Area	FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
GOAL AREA: VII - DESIGN METHODS (Continued)					
<u>Design Procedures</u> (Continued)	<u>Develop potential of and cost reductions for reducing fillet weld sizes in ships. (SR-1286)</u>	Evaluate fillet weld sizing results and consider action to be taken.			
			Consider developing preliminary design procedures for ends of ships to avoid vibration and slamming damage.	Verify the preliminary design procedure for ends of ships.	
<u>Design of welded ship details</u>	<u>Develop a design guide for structural details that will assist designers in selection of sound, cost-effective details. (SR-1292)</u>	<u>Complete design guide for structural details. (SR-1292)</u>			
<u>Collisions and groundings</u>			Establish feasibility for model simulation of groundings according to various scenarios & associated model experiments.	Investigate interim design proposals to limit grounding damage	
			Investigate the common technologies and engineering analysis applicable to both ship collision and grounding problems.	Develop analytical procedures for low energy collision & grounding including studies by ship type.	Develop generalized design guidelines for low energy absorption criteria of parametric studies for various structural configurations.

FISCAL YEAR-1984 PROJECT RECOMMENDATIONS

Table III lists the projects proposed for the Fiscal Year-1984 Program in priority order. This list is based on the composite judgment of the CMS membership who considered the recommendations of the advisory groups. Prospectuses for each of these projects are presented following the table in the same priority order.

As in past years, CMS included more projects than are likely to be funded with the anticipated support. However, the possibility of greater support, the need of the SSC for a reasonable number of projects from which to select, and the possiblity that some projects not initiated in fiscal year 1984 could well be included in the program for the following year, suggest that the preparation of the additional prospectuses is a useful service.

The man-hour figures included in each prospectus are intended to indicate the approximate level of effort (cost) that is estimated to be required for completion of the project.

TABLE III-- RECOMMENDED PROJECTS FOR THE 1984 FISCAL YEAR

PRIORITY	PROJECT TITLE	PAGE
84-1	Development of an On Board Strain Recorder	27
84-2	Structural Behavior After Fatigue	33
84-3	Steels for Marine Structures in Arctic Environments	35
84-4	Corrosion Experience Data Requirements	37
84-5	Ship Hull Strain-Rate Confirmation	40
84-6	Influence of Weld Porosity on the Integrity of Marine Structures	42
84-7	Hydrodynamic Hull Damping	45
84-8	Strategies for Nonlinear Analysis of Marine Structures and Criteria for Evaluating the Results	47
84-9	Comparison of Existing Full-Scale Pressure Distribution Measurements in Oblique and Head Seas for the M/V CORT	51

DEVELOPMENT OF AN ON BOARD STRAIN RECORDER CMS PRIORITY 84-1

Long-Range Goal Area: Response Criteria

OBJECTIVE

The objective of this project is to develop a self-contained on board strain processing and recording instrument that will make use of state-of-the-art electronics to provide more useful engineering data than has been possible in the past.

BACKGROUND

Ship structural designers have long sought measurements of strain (stress) in actual ships at sea. Over recent years, a number of projects have included these measurements. Much, however, remains to be done and progress could be enhanced if the instrumentation could be improved. The recent rapid progress in the miniaturization and cost reduction of electronic sensing, data processing and recording equipment will likely have application here.

Past strain recordings on board ship have been made with the following types of equipment:

1. Scratch gage of the NCRE type: These gages were used on the SEA-LAND McLEAN and other SL-7 ships. They record maximum strain range (+ and - strain reached) over some extended period of time such as four hours. The recording drum then advances and the maximum strain range over the next time period is recorded. One roll of chart paper lasts for about three months. There is no information available as to the strain of a single cycle nor as to the number of times that any value of strain was experienced. A battery powers the clock and advance mechanism.

2. Scratch gage of the brass disk type: This gage is completely mechanical. It records each strain cycle separately by scratching on a disk. The strain cycles are separated from each other by the advancing of the brass disk as each cycle is recorded. The disk will accommodate about two hundred or so stress cycles per revolution. If more cycles are recorded without changing the disk, they will be superimposed on each other. No recording is made of time. These gages are reported to have been used in the SS MANHATTAN during testing in ice.

3. Electrical strain gages: These gages are bonded to the structure and are recorded on tape either locally or remotely. These systems can provide continuous strain readings and can include time signals and other data such as ship's course, wind speed, wave height, etc. They are quite versatile, but the strain readings have a tendency to drift over a period of time. The overall system tends to become expensive and to require frequent expert attention. Water-tightness is a problem.

WORK SCOPE

In an effort to develop a gage which will provide maximum data at minimum cost, it is envisioned that state-of-the-art electronics can be used to provide a package which will be rugged enough for shipboard service and which will record strain against time in a number of different configurations. Such a package might consist of the following components:

- watertight container to enclose the entire package with provision for bolting to the ship structure; total submergence for prolonged periods is important

- linear variable displacement transformer (LVDT) to measure the $\pm$ elongation over the gage span (alternatively an electric strain gage or a vibrating wire strain gage may be used for this function); non-drift performance is important
- electronic mechanism to measure time on a basis of year, month, day, hour, minute, and second (capable of resolving to 1/100 second)
- battery
- microprocessor to manipulate the signals from the strain gage and the clock
- recorder which will preserve simultaneous readings of clock and strain gage for future analysis

The recording of the data may be done in a number of different ways, such as:

A. Record the strain and the time once a second for a one minute duration once every hour. This will permit plotting several wave stress cycles. More frequent measurements would be useful for recording vibration.

B. Count the number of cycles where the Δ strain exceeds some given value. Several values of Δ strain may be used so that a histogram may be drawn. This will be useful in studying fatigue.

C. Record the one-second strain readings for a period of one minute after a given Δ strain in one cycle is measured.

D. Record the one-second strain readings for a period of

one minute before a given Δ strain in one cycle is measured. This will require a continuous short-term memory function which will dump into the permanent record when triggered by a preselected Δ strain.

Other recording configurations will no doubt emerge from a study of how the data may be used.

The data should be stored in such a manner that it may be electronically processed and plotted.

The instrument is to be capable of sensing, processing, and recording useful strain information in connection with the following areas which are presently of interest to the Ship Structure Committee:

- Episodic waves
- Slamming
- Ice loads
- Fatigue measurement
- Vibration
- Underwater stresses in fixed and mobile offshore platforms
- Stresses due to sloshing of liquids in tanks
- Strain rate

The following tasks constitute the major efforts to be accomplished. Phase I is to be completed and approved before Phase II is begun:

Phase I. Design Study

1. Identify the structural strain data needs which could plausibly be met by a self-contained, portable, watertight instrument package.

2. Write a description of its desirable characteristics and performance.

3. Design a strain-vs.-time recorder which meets the following requirements:

   - fits the description of paragraph 1 above
   - uses state-of-the-art electronics with static logic and static memory components
   - self-powered
   - waterproof
   - temperature compensated
   - permanent zero-stress reference capability
   - serviceable on board by operations personnel
   - affordable purchase cost and operating cost

Phase II. <u>Prototype Construction and Testing</u>

4. Build a prototype.

5. Make arrangements for a one-year test of the prototype on an ocean going vessel. An independent method of checking strain readings shall be provided.

6. Carry out the test and evaluate the operation of the equipment.

7. Make recommendations regarding necessary or desirable changes to the prototype.

8. Develop means to electronically analyse and plot the results of the recordings.

9. Analyse the one-year recordings.

10. Prepare a report containing instrument specifications, record of development problems and solutions, software for electronics data processing, instrument operating instructions, and the results of the one-year test.

MAN-HOURS

2500 -- Over two to three years

STRUCTURAL BEHAVIOR AFTER FATIGUE CMS PRIORITY 84-2

Long-Range Goal Area: Materials Criteria

OBJECTIVE

The objective of this study is to determine whether or not fatigue damage is produced in ship plate by cyclic loading, below yield strengths, prior to the occurrence of readily visible cracks.

BACKGROUND

Damage tolerance is normally measured, either in terms of fatigue-crack growth rates or fracture toughness, by conducting laboratory tests on virgin (i.e., previously unstressed) steel plate. For structures in service, however, cracks may propagate into areas that were previously subjected to many cycles of stress below minimum specified yield strength.

If this prior cycling damaged the plate, then data collected on virgin plate would not be conservative, and stress analyses based on these data would also not be conservative. The purpose of this project is to determine whether or not prior cycling does decrease either the fracture toughness or fatigue-crack growth rate of ship steels. Emphasis will be placed on the effect of prior cycling on crack-growth rate.

Tests in both air and salt water should be planned to determine the effect of the adverse environment experienced by marine structures. Both normalized and quenched-and-tempered plates should be used to evaluate any microstructural effects because the lack of uniformity of as-rolled plates could prejudice the results.

WORK SCOPE

The following tasks are to be accomplished:

1. Obtain and fatigue specimens by applying stress for a number of cycles on one normalized marine structural grade plate and one quenched-and-tempered marine structural grade plate to their endurance limit in air. The number of fatigue cycles should be as large as practical for the applied stress-time pattern, and post-strain aging should be controlled.

2. Conduct both fracture toughness and crack-growth rate tests on the prefatigued plates and on virgin plate control specimens. All-fracture toughness tests should be done in air while crack-growth-rate tests should be conducted in both air and salt water.

3. Measure damage in terms of changes in both fracture toughness and crack-growth rate, i.e., $da/dN = F(K)$. Emphasis should be on the latter.

4. Write a report analyzing the results and the impact on service structural fitness of prefatigued, but uncracked, plates. This report should include specific recommendations for additional work if fatigue damage is found. If an effect is found, as-rolled steels and weldments should be considered. All test materials and specimens should be preserved for possible future examinations such as optical and electron microscopy.

MAN-HOURS

4000 -- Two years

STEELS FOR MARINE STRUCTURES
IN ARCTIC ENVIRONMENTS

CMS PRIORITY 84-3

Long-Range Goal: Materials Criteria

OBJECTIVE

The objective is to review the literature and service experience on steel usage in non-marine cold weather applications to evaluate the usefulness of these steels for marine structures in an arctic environment.

BACKGROUND

The development of resources in arctic regions will soon require marine structures capable of withstanding combinations of very low temperature, high stress, and fatigue. For such structures to be designed and fabricated with some degree of confidence, reliable information on steels and environment is required. This information would then be incorporated in the development of various rationales for the establishment of guidelines or requirements to ensure proper selection and utilization of steels in these arctic structures.

One project to develop a fracture-mechanics rationale for the establishment of toughness requirements on steel weldments is already underway at the National Bureau of Standards. Work of this type dictates the need for a program to survey the properties of steels performing successfully in the arctic environment. The properties of these steels should be recognized prior to the publication of any fracture-control-type guidelines that may be so conservative in nature as to rule out these same successful applications.

WORK SCOPE

The following tasks are considered essential to the project:

1) Conduct survey, review literature, and evaluate reports and service experiences, including limitation caveats, for steels which are currently employed or designated for use in arctic structures.

The following topics should be considered while conducting the review and evaluation:

- Purchase specifications
- Actual mechanical properties and thicknesses with particular emphasis on fracture and fatigue
- Environmental conditions
- Fabrication procedures
- Service experiences, including limitation caveats
- Criteria for existing configuration and loading of structure
- Inspection and maintenance schedule

2) Prepare a report to present the results of the study. Note, where appropriate, where insufficient information is available.

3) Recommend new programs to meet these needs on existing materials and, if appropriate, identify the need for improved steels and welding procedures for arctic marine applications.

MAN-HOURS

1500 -- One year

CORROSION EXPERIENCE DATA REQUIREMENTS CMS PRIORITY 84-4

Long-Range Goal Area: Materials Criteria

OBJECTIVES

The objectives of this project are to define corrosion data requirements and data gathering methodology for a new survey upon which to eventually base a more rational approach for corrosion margins.

BACKGROUND

Corrosion is a major factor contributing to the eventual failure of a structure in a marine environment. Allowance for corrosion, in the form of initially added structural material, provision of surface protection, or ultimate retirement of the structure when its anticipated residual strength has reached a minimum acceptable level, has considerable economic significance. Important economic benefits could be realized if replacement of a structure could be deferred and the life extended through a better understanding of the interaction between state of corrosion and residual strength. The first step in this understanding would be increased knowledge of the extent of various types of corrosion, as a function of the particular vessel or type of vessel and the service to which it is to be exposed. Offshore structures may be considered in a future project.

Corrosion is affected by a large number of parameters and prediction of the extent of various types of corrosion without undue conservatism, is considered best done statistically, using data acquired from actual ship operations. Large amounts of such data are available in operators' records and files, but rarely is there sufficient information on either the characteristics of the corrosion

for residual strength analysis, or on all of the parameters that can affect various types of corrosion for adequate corrosion prediction. Accordingly, a new program of corrosion data gathering that will use a new vessel or fleet of vessels is required. In turn, the first step in this activity is to study how such a program should be conducted, followed by understanding the type of data to be collected, the parameters to be recorded, and the type of documentation and instrumentation required. Such data collection should include: (a) corrosion details at various locations on the ship structure, but particularly strength critical areas; (b) ship operations, such as route, speeds, sea conditions, time and location at dockside, cargo, etc.; (c) ship parameters, such as size, weight, structural materials, corrosion protection, etc.; and (d) ship history, including maintenance, repairs, etc.

Based on the results of this project, subsequent projects should include corrosion data gathering (requiring cooperation with a ship fleet operator), statistically based corrosion prediction, and an approach to residual strength prediction.

WORK SCOPE

The following tasks are considered essential to the project:

1. Review sources of information from ship owners and operators, U.S. Coast Guard, ABS, and similar international bodies as well as appropriate industrial institutions. Determine the type of corrosion data normally collected, the methods of collection and documentation used, the types of corrosion typically observed, and their relationship to critical areas of the structure.

2. Formulate a program of corrosion data collection for the purpose of subsequently improving the prediction of corrosion significant to structural strength. Define the data required, the instrumentation required (if any), and the form of documentation.

3. Conduct interviews with selected ship operators to verify the practicality of the program developed under item 2. Revise the program accordingly.

4. Prepare a report to present the results of the study, particularly defining corrosion data requirements and data gathering methodology. Make recommendations with respect to a data gathering, processing and reporting program.

MAN-HOURS

1000 -- One year

SHIP HULL STRAIN-RATE CONFIRMATION **CMS PRIORITY 84-5**

Long-Range Goal Area: Materials Criteria

OBJECTIVE

The objective of this study is to confirm the preliminary estimates of ship hull strain rates, utilizing existing full-scale data.

BACKGROUND

The Ship Structure Committee recently completed a feasibility study on the determination of strain rates in ship structures (1). The committee originally recognized that since the toughness of ship steels varies with loading and resulting strain rates, it is necessary to define the range of strain rates encountered by ships in service. This information would then allow designers to evaluate the conservatism of the steel testing techniques that are used to classify ship steel toughness.

The evaluation of existing data from shipboard instrumentation programs indicated that it is feasible to obtain strain-rate information within the frequency limitations of the data acquisition techniques employed (i.e., low-pass filtering).

Preliminary estimates of strain rates from existing data indicate that ship service experience produces strain rates up to 10^{-3} in/in/sec. This strain-rate approach, which is used for fracture-mechanics toughness testing (10^{-5}in/in/sec.), is considerably slower than the Charpy test strain rate (10^{1} in/in/sec).

Because only a sampling of the data was examined, this new project is aimed at corroborating and validating the strain rate of 10^{-3} in/in/sec. This would be accomplished by an in-depth analysis

of the existing strain rate data on the SL-7 class ships (1). Software and analytical techniques developed for this project could be useful for future instrumented tests.

Reference

(1) SR-1285 - Determination of the Range of Shipboard Strain Rates, Giannotti and Associates.

WORK SCOPE

The following tasks are considered essential to the project:

1. Process selected existing SL-7 analog and digital full-scale ship response data to obtain strain rates.

2. Develop computer software to differentiate the strain data with respect to time.

3. Analyze the reduced strain-rate data, including collation of data with respect to ship speed, heading, loading, and encountered wave conditions.

4. Perform probabilistic analyses to establish distribution of strain rates for various sea states.

5. Write report summarizing calculations, analytic techniques, results, and recommendations for future work.

MAN-HOURS

1000 - one year

INFLUENCE OF WELD POROSITY ON THE INTEGRITY OF MARINE STRUCTURES **CMS PRIORITY 84-6**

Long-Range Goal Area: Fabrication Techniques

OBJECTIVE

The objective of this project is to obtain a better understanding of the dependence of the integrity of marine structures on weld porosity.

BACKGROUND

Over the past decade, considerable progress has been made in technologies used to assure the structural integrity of marine structures. These include new methods for stress and load analysis, fracture mechanics, and improved nondestructive inspection (NDI) techniques. This continually developing body of knowledge should be applied to the assessment of the influence of many types of weld defects on the integrity of marine structures.

This project will consider only the influence of porosity. Other defects will be considered in the future. Although there is considerable information on the effect of porosity on the mechanical properties of weldments and on the ability of various NDI techniques to detect this type of flaw, it is outdated. Information on points gathered in the last ten years should be coupled with appropriate analytical techniques.

WORK SCOPE

The following tasks are considered necessary to meet the objective:

1. Review and summarize available information on the influence of porosity on marine weldments.

2. Determine the functional dependence of the integrity of marine structures on weld porosity by conducting fracture-mechanics parametric studies using a fatigue stress spectrum and maximum credible stesses based on SL-7 and other ship load data banks, fatigue-crack-growth data, and fracture-toughness data for materials used in marine construction. Limitations of currently available inspection techniques should be considered.

3. Prepare a report to present the results of the study. Recommend, where appropriate, new programs to meet the needs where insufficient information is available.

MAN-HOURS

1500 -- One year

HYDRODYNAMIC HULL DAMPING CMS PRIORITY 84-7

Long-Range Goal: Response Criteria

OBJECTIVE

The objective of the project is to prepare a program for the development and validation of procedures for estimating the longitudinal distribution of energy dissipation (damping) associated with the principal flexural or "beam" modes of ship hull vibration.

BACKGROUND

Accurate calculation of the response of a ship's hull to low-frequency dynamic excitation depends very strongly on the ability to calculate the energy dissipation caused by interaction between the hull and the water both by radiation and by viscous shear. This problem is particularly acute in the low-frequency range (0.5 to 10.0 Hz) associated with the free-free beam bending modes. While there is some small contribution from structural damping and a larger, variable amount due to cargo interaction, it is the hydrodynamic damping that must be relied on principally to control the vibration amplitude.

Up to now, the usual design practice has been to base this calculation on rigid hull motion. There is considerable evidence, mainly from model tests but some from full-scale tests of both naval and merchant vessels, that the amount of damping is greatly influenced by the hull flexibility.

Early efforts on this subject resulted in the set of recommendations reported in SSC project SR-1261 "Hull Structural Damping Data." These recommendations require amplification.

WORK SCOPE

The current contemplated program would be carried out in

three phases. Phase I is the only portion being sought in this prospectus and is a background and planning document for Phases II and III. This is a relatively modest effort that essentially seeks an evaluation of experimental data readily available to the contractor. From this information, the contractor should develop specific plans for using commercially available excitation equipment and instrumentation to obtain the information necessary for a rational approach to the estimation of energy dissipation in beam bending modes of ships' hulls. This program will include the other two phases.

Phase II will develop specific calculation procedures and determine appropriate numerical coefficients. Further model testing may or may not be required depending on the completeness of the information now available.

Phase III will verify these procedures with full-scale tests.

The following tasks are considered necessary to meet the objective of Phase I:

1. List and evaluate test and analytical information related to beam bending hull damping from open reports and technical literature now in the contractor's files.

2. Based on this current information, define in specific terms a project for developing an analytical procedure for calculating the damping due to the interaction between the flexible hull and the water both at anchor and underway, and write a work scope for Phase II of the program. If further model tests are deemed necessary, they should be justified, and the specific test objectives and methods should be given.

3. Develop a plan for Phase III of the program to evaluate and verify Phase II prediction methods by means of full-scale tests.

4. Write the Phase III work scope. Among the topics to be explicitly specified in this work scope are:

a) Specific test conditions and methods.

b) Specifications for commercially available testing equipment and instrumentation.

c) Specific procedures for data reduction and presentation which will produce information useful in design.

d) Determination of appropriate and available ship types.

e) Appropriate operating conditions for the ships listed in d) with some direct indication from ship operators that these tests could be run and that the operators would co-operate.

5. Estimate separately the man-hours necessary for Phases II and III with whatever supporting detail is appropriate.

The work scopes for Phases II and III should be in such detail that they can be used as the technical basis for preparing requests for proposals.

MAN-HOURS

500 -- Six months (Phase I only)

STRATEGIES FOR NONLINEAR ANALYSIS OF MARINE STRUCTURES AND CRITERIA FOR EVALUATING THE RESULTS CMS PRIORITY 84-8

Long-Range Goal Area: Response Criteria

OBJECTIVE

This project is intended to review the available strategies for performing and evaluating nonlinear analysis of marine structures under random loading and provide a rationale for selecting among them with particular emphasis on how to interpret the response extremes on a consistent reliability basis.

BACKGROUND

Ships and marine structures are subjected to random excitation by environmental elements. There is a need to analyze their response to these excitations from a probabilistic approach. Existing formulations are generally applicable only to linear systems and the conditions for superposition must be valid. For the nonlinear state, equivalent methods of analysis are not as well developed, nor are criteria for evaluating the results.

Nonlinearities may arise in both the loading and response of marine structures, for example:

1. Nonlinear drag force parameters, such as velocity-squared and relative motion.
2. Free surface effects such as member immersion/emergence, deck overflooding, and slamming.
3. Large displacement in compliant structures, marine risers, and catenary moorings.
4. Nonlinear lift forces.
5. Material nonlinearities, such as plasticity and creep.

6. Geometric nonlinearities, such as postbuckling and large deflection.

7. Soil-structure interaction in bottom-supported marine structures.

8. Hydroelastic response, such as vortex shedding and strumming.

The need for considering nonlinear effects in the extremes of loading and response may be regarded as an integral part of a realistic ultimate strength and reliability evaluation, which must deal with all failure modes even though the expected behavior may be more or less linear under normal conditions. Nonlinear time-domain, dynamic analysis computer programs have been developed to handle many of these problems. Some of these are specialized to a particular type of structure and loading. Even so, they are always complex and expensive to run; thus, some approach for reducing the complexity and time span covered by detailed analysis is generally taken. Strategies in use include, among others:

1. Selection of design wave based on statistics of the sea state (e.g., Longuet-Higgins), followed by deterministic analysis for this wave.

2. Conditional random wave simulation of a selected extreme event, based on recorded wave profile and hindcast directional spectrum.

3. Selection of one or more design segments of a random sea, based on full-storm (or voyage) duration screening analysis of a simplified representation of the structure, followed by a detailed analysis for the selected random wave time segments.

4. Random analysis for a representative time period followed by extrapolation to the extreme response using non-Gaussian statistics.

5. Nonlinear analysis in regular waves to establish transfer functions (which may vary with sea state) to be used in subsequent linear analysis.

6. Analysis of a reduced model by one of these approaches, followed by application of the extreme forces to a more detailed model.

For most of these strategies, a statistical interpretation of the results is required; yet criteria for doing this are not well established. Some strategies yield variable results from multiple trials, and different strategies appear to yield inconsistent answers. Guidelines for selecting rational strategies and calibrating their results in terms of reliability are needed.

WORK SCOPE

The proposed project is intended to focus on generic procedures for nonlinear analysis in terms of strategies and interpretation. This does not imply a review of the detailed methods and analysis tools available for particular nonlinear problems or the broader issues of marine structure reliability. The following tasks are considered essential in meeting the objective:

1. Review the types of nonlinear behavior of interest for various classes of marine structures, together with the generic types of nonlinear physical models with which they are analyzed. This should be a limited task to plan the rest of the study in context.

2. Describe the probabilistic basis of selection of expected extreme loads and responses for structures.

3. Evaluate the various probabilistic, reliability, and statistical approaches which may be taken for performing and interpreting nonlinear analysis in terms of:

a) Their suitability for the various physical problems, available analytical models, and cost constraints.

b) Their probabilistic interpretation, in terms of consistency with item (2) and with each other.

4. Describe consistent methodologies for selecting the modeling and analysis strategy for interpreting the results.

5. Prepare recommendations for further research.

6. Write a report directed to designers currently attempting to use this advanced technology.

MAN-HOURS

1000 -- one year. This has been intentionally limited so as to keep the scope of the effort focused on the objective. The choice of an investigator with appropriate expertise and insight will be crucial.

COMPARISON OF EXISTING FULL-SCALE PRESSURE DISTRIBUTION MEASUREMENTS IN OBLIQUE AND HEAD SEAS FOR THE M/V CORT CMS PRIORITY 84-9

Long-Range Goal Area: Response Criteria

OBJECTIVE

The objective of this project is to compare full-scale pressure distribution data for the M/V CORT in oblique waves with similar data in head seas in order to generate a data base for further computer program validation.

BACKGROUND

Full-scale pressure distribution measurements have been made on the M/V CORT in both head seas and oblique waves. Comparing these measurements will establish whether hull pressures are more critical in the head sea or oblique sea condition. The present (but temporary) existence of a model for the M/V CORT suggests that this determination be made promptly to assess the importance of oblique wave model testing. The results may indicate the need to extend the work to better define the directionality of the wave energy.

WORK SCOPE

The following tasks would comprise the major efforts:

1. Obtain existing full-scale test results for the M/V CORT and make a comparison of head wave test results with oblique wave results.

2. Make a determination of the relative criticality of head seas versus oblique seas on hull pressures based on the full-scale test results.

3. Recommend whether future model tests in oblique seas would be desirable, and why.

4. Prepare and publish a final report of the comparison outlined above.

MAN-HOURS

1000 - One year

PROJECT RECOMMENDATIONS FOR INTERNATIONAL COLLABORATION

The SSC has continually fostered the exchange of technical information with shipbuilding research activities outside of the United States. This has been accomplished through the direct exchange of research reports with appropriate foreign activities and individuals, continued support of the International Institute of Welding (IIW) and the International Ship Structures Congress (ISSC), and personal discussion with research investigators abroad.

In developing the 1984 research program, the CMS examined two areas of interest:

Worldwide Coastal Offshore Meteorology and

Worldwide Coastal Offshore Soils.

These programs would provide information needed by the designer of a mobile drilling unit whose client may well be an independent operator seeking to obtain the most versatile structure practicable. While, in all probability, the fixed platforms represent investment by owners who make mandatory extensive site surveys on their own account. Therefore, because of the nature and availability of the data for these investigations, CMS recommends that this work be accomplished by an international body such as the International Association of Classification Societies (IACS) or the International Ship Structures Congress (ISSC), under the endorsement of SSC.

WORLDWIDE COASTAL OFFSHORE METEOROLOGY

OBJECTIVE

The objective of this project is to gather and publish information with respect to wind and wave climatology for coastal regions of the world that represent present and probable future areas for operation of mobile offshore drilling units.

BACKGROUND

Over the past 30 years the search for offshore oil and gas has spread from the Gulf of Mexico to a large portion of the coastal waters of the world. It is expected that this expansion will continue in the decades to come.

During this period more than 700 Mobile Offshore Drilling Units (MODUs) have been constructed. The present construction rate is over 100 units per year and it appears likely that the total active number may well exceed 2000 in the next ten to fifteen years. The average price is presently in the order of $30,000,000 per rig.

Several different types of MODUs are in use. The composition of the present fleet is about as follows (Ocean Industry, September 1982):

Submersibles (column stabilized, bottom supported)	39
Drillships and barge class vessels (ship shaped, floating, anchored)	95
Semi-submersibles (column stabilized, floating, anchored)	175
Jack-Ups (bottom supported; about 1/3 with mat foundation and 2/3 with independent legs)	463

The design characteristics of these rigs vary greatly, depending largely upon what part of the world was seen as the principal market at the time the rig was built. Design winds vary from 50 to over 100 knots; design wave heights vary from about 20 feet to about 100 feet; and design soil pressure for bottom-supported rigs varies from about 500 pounds per square foot to about 5000 pounds per square foot. There has been much movement of these rigs from one part of the world to another. The buyer, the designer, and the builder must look ahead for twenty years or so to select those design requirements which will permit a wide enough area of safe performance to keep the rig profitably employed. Inasmuch as the primary function of MODUs is to do exploratory drilling, it is expected that much of the future work will be in areas that are presently classed as frontier.

The perspective of the buyer/designer/builder would be helped if they had the information to relate wind and wave data for well known areas, such as the Gulf of Mexico and the North Sea, to the many other but less well known areas of the world that are present or potential drilling provinces. This information should be in a form which permits engineering calculations for items such as anchor line pulls (for semi-submersibles and drill ships), soil bearing pressures (for jack-ups and submersibles), wind and wave structural loadings, and fatigue stresses. Also, it should be in the same format for different geographical areas so that the requirements are easily comparable.

There are many potential operating areas for which the desired information is not available in detail, but there are much

world-wide meteorological data which may be used to develop approximate wind and wave probabilities for the various regions.

The primary purpose of this study is to improve the long-term frame of reference of the buyers, designers, and builders of MODUs. If the comparative world-wide data on wind and wave climatology is in readily available form, their choice of optimum design requirements for future rigs can be more rational. These data will likely prove useful to the operators of these rigs.

WORK SCOPE

The following tasks constitute the major efforts to be accomplished:

1. Provide a map of the world which shows present and probable future drilling areas in water depths up to, say, 600 feet.

2. Provide individual maps of local areas. These maps are to have water depth contours and are to indicate how the local areas fit into generalized patterns of wind and wave severity. A fairly large number of these local maps will be required.

3. Provide a written description of world-wide wind and wave activity which outlines differences between regions. Discuss occurances such as hurricanes and monsoons, which have a controlling effect upon offshore design and operating practices.

4. Show relative wind severity in the different regions using a presentation such as shown on Figures 1 and 2.

5. Show relative wave heights in the different regions using a presentation such as shown on Figures 3, 4, and 5. Indicate the probability of various wave periods that may be associated with the range of wave heights. Wave sizes may be shown for relatively deep

water and the effect of shoaling may be indicated as a generalized effect.

6. For each of the drilling areas selected in Task 2, determine the appropriate curves for winds and waves as shown in Tasks 4 and 5. These data are then to be presented on the local area maps of Task 2.

7. Define relevant terms such as: fastest mile wind, one-minute wind, average wind, gust, average wave height, significant wave height, maximum wave height, average period, significant period, and modal period, etc. Indicate the probable relationship between similar terms.

8. Provide a numerical summary that relates areas in square miles to such factors as: identification of regions, water depths, wind velocities, and wave heights.

9. Indicate the degree of uncertainty that applies to each of the regions for which wind and wave data is given.

NOTE: Detailed methods of presenting wind and wave data are shown for illustration only. Other methods which will accomplish the same result may be suggested by the proposer.

MAN-HOURS

2000 over two years

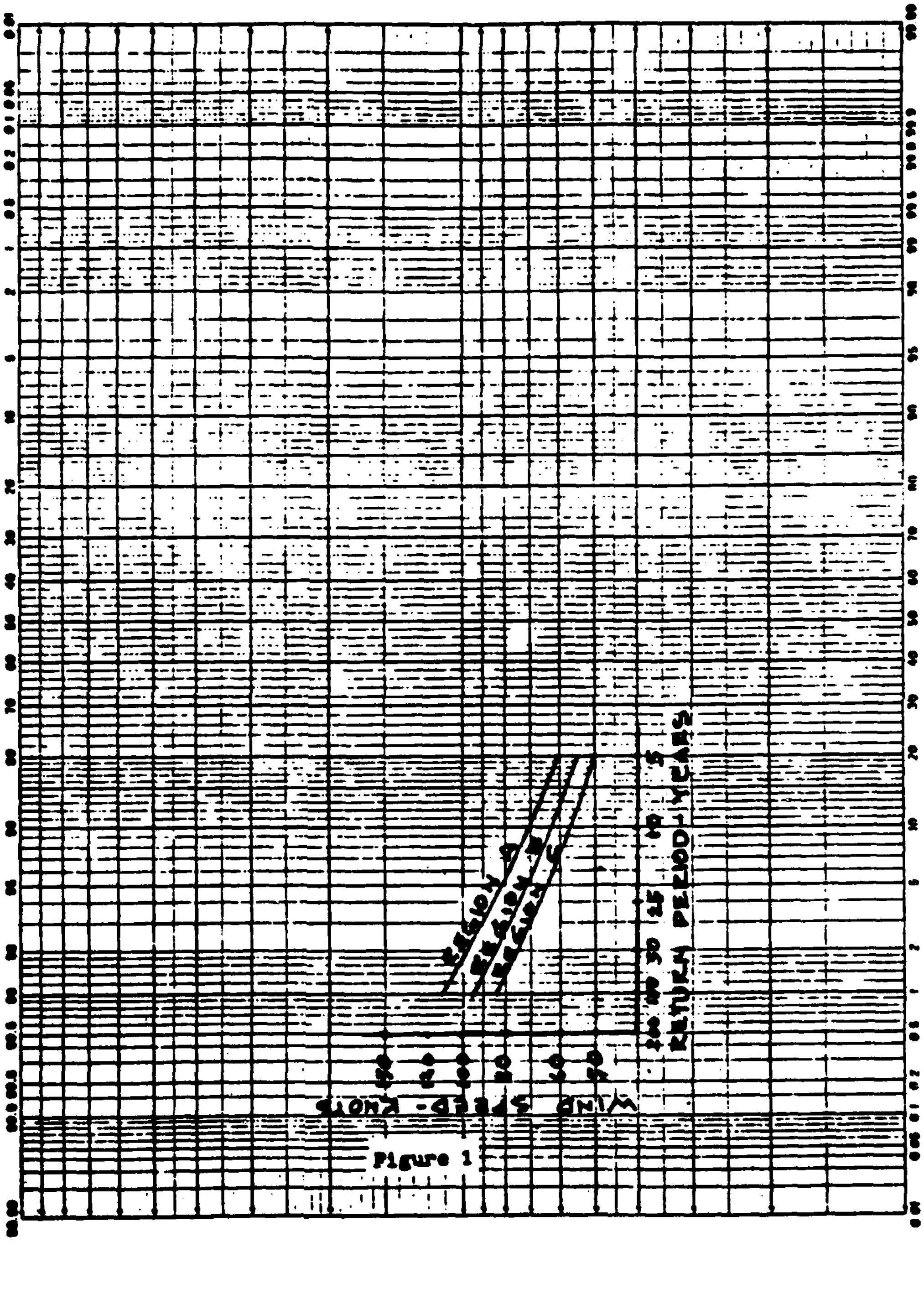
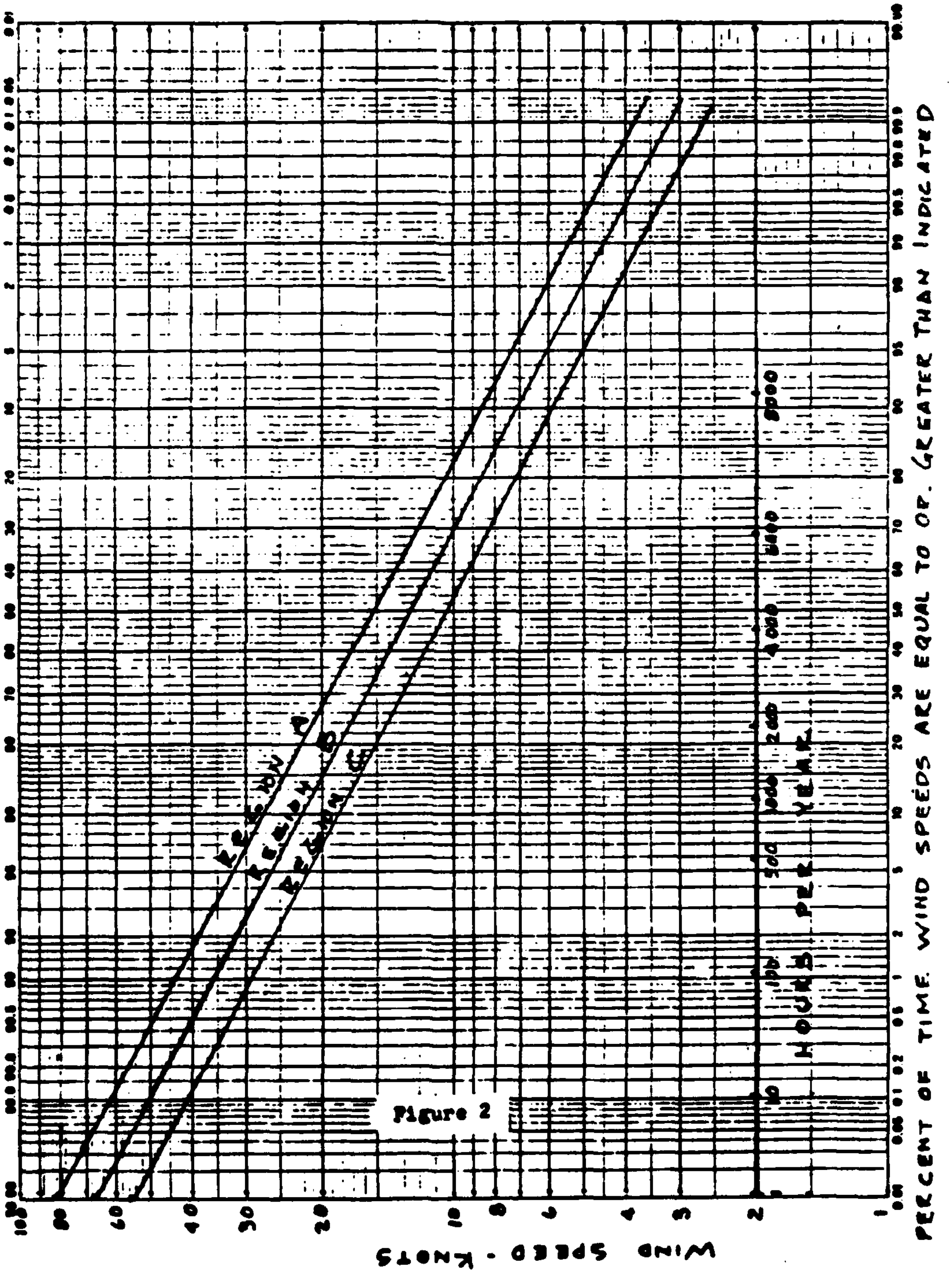


Figure 1



REGION A
REGION B
REGION C
WIND SPEED - KNOTS
HOURS PER YEAR
PERCENT OF TIME WIND SPEEDS ARE EQUAL TO OR GREATER THAN INDICATED

Figure 2

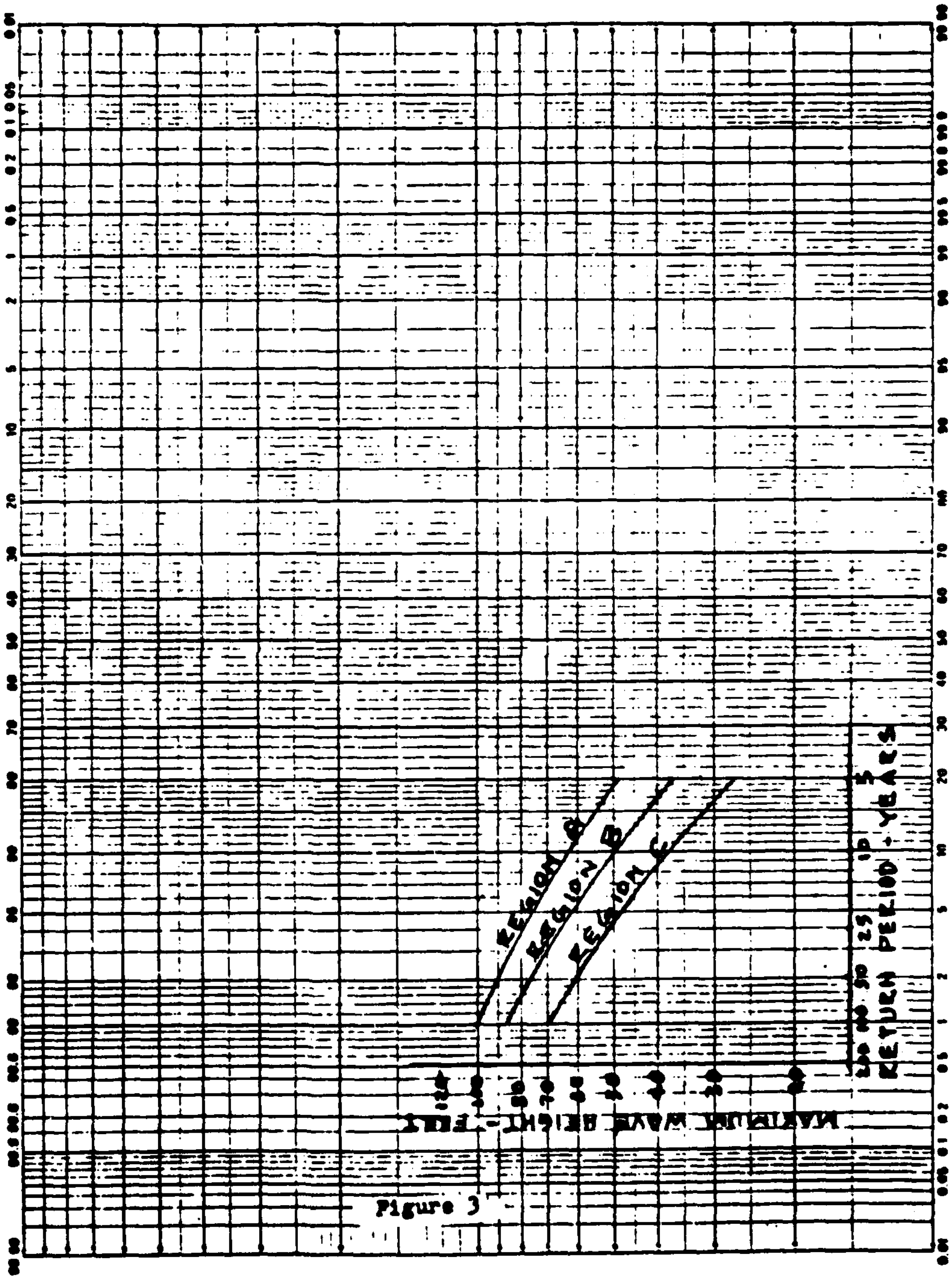

MAXIMUM WAVE HEIGHT - FEET
RETURN PERIOD - YEARS
REGION A
REGION B
REGION C

Figure 3

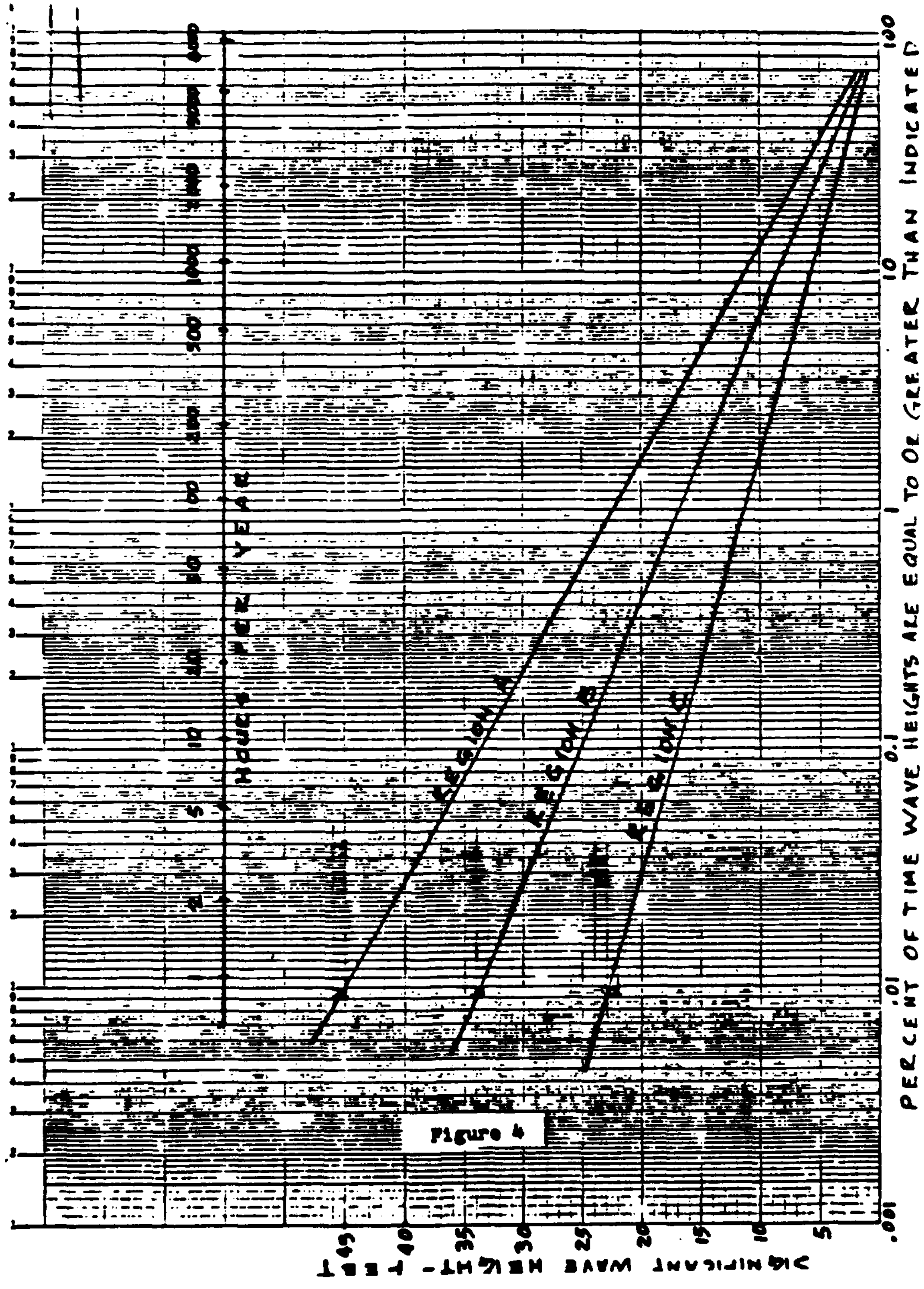

PERCENT OF TIME WAVE HEIGHTS ARE EQUAL TO OR GREATER THAN INDICATED
.001
.01
0.1
1
10
100
SIGNIFICANT WAVE HEIGHT - FEET
5
10
15
20
25
30
35
40
45
HOURS PER YEAR
REGION A
REGION B
REGION C

Figure 4

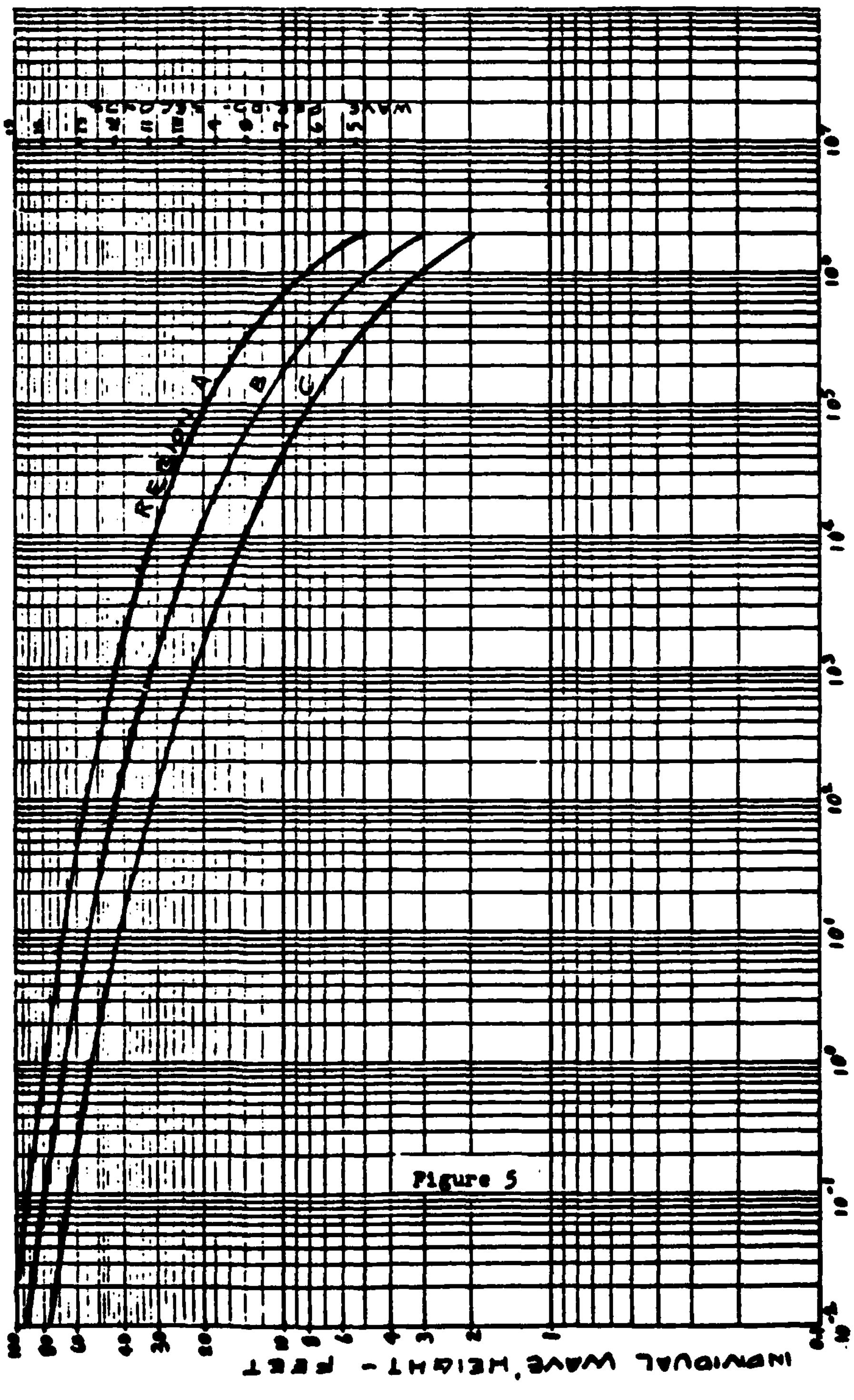

WAVES PER YEAR EQUAL TO OR GREATER THAN HEIGHT SHOWN
INDIVIDUAL WAVE HEIGHT - FEET
WAVE PERIOD - SECONDS
REGION A
B
C

Figure 5

WORLDWIDE COASTAL OFFSHORE SOILS

OBJECTIVE

The objective of this project is to gather and publish information with respect to soil characteristics for coastal regions of the world that represent present and probable future areas for operation of mobile offshore drilling units.

BACKGROUND

Over the past 30 years, the search for offshore oil and gas has spread from the Gulf of Mexico to a large portion of the coastal waters of the world. This expansion is expected to continue in the decades to come.

During this period more than 700 Mobile Offshore Drilling Units (MODUs) have been constructed. The present construction rate is over 100 units per year and it appears likely that the total active number may well exceed 2000 in the next ten to fifteen years. The average price is presently in the order of $30,000,000 per rig.

Several different types of MODUs are in use. The composition of the present fleet is about as follows (Ocean Industry, September 1982):

Submersibles (column stabilized, bottom supported)	39
Drillships and barge class vessels (ship shaped, floating, anchored)	95
Semi-submersibles (column stabilized, floating, anchored)	175
Jack-Ups (bottom supported, about 1/3 with mat foundation and 2/3 with independent legs)	463

The design characteristics of these rigs vary greatly, depending largely upon what part of the world was seen as the principal market at the time the rig was built. Design winds vary from 50 to over 100 knots; design wave heights vary from about 20 feet to about 100 feet; and design soil pressure for bottom-supported rigs varies from about 500 pounds per square foot to about 5000 pounds per square foot. There has been much movement of these rigs from one part of the world to another. The buyer, the designer, and the builder must look ahead for twenty years or so and to select those design requirements which will permit a wide enough area of safe performance to keep the rig profitably employed. Inasmuch as the primary function of MODUs is to do exploratory drilling, it is expected that much of the future work will be in areas that are presently classed as frontier.

The perspective of the buyer/designer/builder would be helped if they had the information to relate soil characteristics for well known areas, such as the Gulf of Mexico and the North Sea, to the many other but less well known areas of the world that are present or potential drilling provinces. This information should be in a form which permits engineering calculations, and it should be in the same format for different areas so that the properties are easily comparable.

The primary purpose of this study is to improve the long-term frame of reference of the buyers, designers and builders of MODUs. Their choice of optimum design requirements for future rigs can be more rational. If they have, in readily available form, the

comparative world-wide data on soil characteristices. It is likely that these data will likely prove useful to the operators of these rigs as well.

WORK SCOPE

The following tasks constitute the major efforts to be accomplished:

1. Provide a map of the world which shows present and probable future drilling areas in waters up to, say, 600 feet deep.

2. Provide individual maps of local areas. These maps are to have water depth contours and are to show the various types of soils that exist throughout the area shown. A fairly large number of these local maps will be required.

3. Provide a written description of the geological history that has caused the development of different soil characteristics in different areas. Show typical soil composition profiles and soil strength profiles. These profiles may be given identifying numbers and be used to describe the types of soils required in Task 2.

4. Discuss the soil foundation requirements of various types of bottom-supported MODUs. Describe soil problems which may affect the various types of units. Indicate how these requirements and problems relate to the soil data given under Tasks 2 and 3.

5. Provide a numerical summary that relates areas in square miles to such factors as identification of region, water depths, and soil characteristics.

6. For each region indicate other factors which may affect MODU use such as slope of bottom, irregularities of bottom, protruding rock formations, and shallow sand lenses.

7. Indicate the degree of uncertainty that applies to each of the regions for which the soils characteristics are given.

MAN-HOURS

2000 - two years

REVIEW OF ACTIVE AND PENDING PROJECTS

This section of the report covers current projects funded with FY-1982 (or earlier) funds, others that have been continued with FY-1983 funds, and those which are anticipated to be supported with FY-1983 funds. These projects, listed in Table IV, constitute the current program. The majority of projects are for one year's duration; multiyear projects are funded incrementally on an annual basis.

Project descriptions, including the project number and title, the name of the principal investigator and his organization (where these have been determined), and the activation date and funding (where applicable) are provided. The appropriate SSC long-range goal is also noted, and a very brief statement of the objective of each project is given. These are followed by a short description of the present status of the project.

TABLE IV -- REVIEW OF ACTIVE AND PENDING PROJECTS

PROJECT NO.:	SR-1256
PROJECT TITLE:	INVESTIGATION OF STEELS FOR IMPROVED WELDABILITY IN SHIP CONSTRUCTION
INVESTIGATOR:	Dr. L. F. Porter
CONTRACTOR:	U.S. Steel Corporation, Monroeville, PA
ACTIVATION DATE:	September 29, 1978
CONTRACT FUNDING:	$319,108
SSC LONG-RANGE GOAL:	Materials Criteria
CONTRACT NUMBER:	DOT-CG-80588-A

OBJECTIVE

The objective of this multi-year study is to select the optimum materials and welding parameters to improve resistance to degradation of the heat-affected-zone (HAZ) properties in weldments made with high-deposition rate processes.

STATUS

Simulated grain-coarsened HAZs were produced for each of 12 experimental steels. Metallographic examinations of quenched specimens clearly showed the development of transformations in the HAZs. Studies to clarify the mechanisms responsible for the adverse effect of high nitrogen (N) content in titanium (Ti) and titanium-plus-vanadium steels have begun. Additionally, specimens from three new low nitrogen (0.004 percent N) steels (produced as 100-lb, vacuum-melted ingots, rolled to 1/2-in plate, and normalized) are being prepared for examination to determine if the strength of normalized plate steels can be increased without adversely affecting weld HAZ toughness.

PROJECT ADVISORY COMMITTEE

Dr. H. I. McHenry, Chairman, National Bureau of Standards, Boulder, CO
Prof. T. W. Eagar, Mass. Inst. of Technology, Cambridge, MA
Dr. M. Korchynsky, Union Carbide Co., Pittsburgh, PA
Dr. J. L. Mihelich, Climax Molybdenum Co., Ann Arbor, MI
Dr. J. C. Baker, Bethlehem Steel Corp., Bethlehem, PA
Prof. D. L. Olson, Colorado School of Mines, Golden, CO

PROJECT NO:	SR-1276
PROJECT TITLE:	LONG-TERM CORROSION FATIGUE OF WELDED MARINE STEELS
INVESTIGATOR:	Dr. O.H. Burnside
CONTRACTOR:	Southwest Research Institute, San Antonio, TX
ACTIVATION DATE:	September 29, 1980
CONTRACT FUNDING:	$144,810
SCC LONG-RANGE GOAL:	Materials Criteria
CONTRACT NUMBER:	DTCG23-80-C-20028

OBJECTIVE

The objective of the research is to define and evaluate currently available technology for assessing the long-term corrosion fatigue behavior of welded joints in sea water, and to develop a plan for long-term future efforts, if required.

STATUS

Although a lengthy interruption occurred in the study for contractual reasons, work is now proceeding on a simplified reliability analyses format. However, a reliability model can not be validated because reasonable field data are unavailable. A sensitivity analysis using a probabilistic approach will be addressed using simplified relationships, rather than using a Monte Carlo analysis technique. Because the intent of this study is to investigate the "strength side" of the design equation, the reliability studies will focus on the collection of statistical information on fatigue and fracture strengths of materials under corrosive environments.

FATIGUE PROGRAM ADVISORY COMMITTEE

Mr. P. W. Marshall, Chairman, Shell Oil Co., Houston, TX
Dr. R. D. Glasfeld, General Dynamics, Quincy, MA
Prof. P. H. Wirsching, University of Arizona, Tucson, AZ

PROJECT NO:	SR-1277
PROJECT TITLE:	ADVANCED METHOD FOR SHIP MOTION AND WAVE-LOAD PREDICTIONS
INVESTIGATOR:	Mr. J.C. Oliver
CONTRACTOR:	Giannotti and Associates, Inc., Annapolis, MD
ACTIVATION DATE:	September 29, 1980
CONTRACT FUNDING:	$99,534
SSC LONG-RANGE GOAL:	Loads Criteria
CONTRACT NUMBER:	DTCG23-80-C-20032

OBJECTIVE

The objective of the study is to develop a method and appropriate computer program for predicting ship motions and distributed wave loads, taking into account the hull form shape above and below the still waterline, including the three-dimensional hydrodynamic coefficients.

STATUS

Hydrodynamic models are being coupled that use a two-dimensional (2-D) strip-technique model to provide the existing normal velocity on the surface of the hull and a three-dimensional (3-D) source-time-simulation technique model to determine the transient loading and response. How to compare the pressure distribution results with theory; how to transfer feedback from the 3-D to the 2-D model; how to incorporate other loads at a later stage such as slamming, green water, and flow; and how frequency selection becomes involved in a rigid-body motion problem are questions still being investigated.

PROJECT ADVISORY COMMITTEE

Dr. O. H. Oakley, Jr., Chairman, Gulf Research & Development Company, Houston, TX
Prof. N. A. Hamlin, Webb Institute of Naval Architecture, Glen Cove, NY
Prof. W. H. C. Maxwell, University of Illinoi^, Urbana, IL
Dr. W. R. Porter, State University of NY, Maritime College, Bronx, NY

PROJECT NO: SR-1283
PROJECT TITLE: PERFORMANCE OF UNDERWATER WELDMENTS
INVESTIGATOR: Mr. E. B. Norris
CONTRACTOR: Southwest Research Institute, San Antonio, TX
ACTIVATION DATE: July 6, 1982
CONTRACT FUNDING: $195,308 (Two-year project)
SSC LONG-RANGE GOAL: Fabrication Techniques
CONTRACT NUMBER: DTCG-23-82-C-20017

OBJECTIVE

The objectives of the proposed research are to gather data on the mechanical properties of wet and wet-backed underwater weldments and to provide guidelines relating these properties to design performance.

STATUS

Tasks 1, 2, and 3, which cover the review, synthesis, and updating of existing data, have been completed and reported. Very little publication data exist and far less data have been made available from operators, fabricators, and repairers of underwater marine structures. Therefore, Phase II is now underway to conduct a statistically valid series of laboratory tests in which the performance of Type B underwater welds can be compared to existing data on in-air welds. The tests include 23 grooved weld specimens, 3 fillet weld specimens and 3 all-welded-metal specimens, .36 (with ferretic electrode) and .46 (with austinetic electrode) carbon equivalent steel plate in half and one-inch thicknesses, for 0-, 33-, 115-, and 190- foot depths.

PROJECT ADVISORY COMMITTEE

Prof. D. L. Olson, Chairman, Colorado School of Mines, Golden, CO
Mr. C. E. Grubbs, D&W Underwater Welding Services, Inc., Slaughter, LA
Dr. S. Ibarra, Gulf Science & Technology Co., Pittsburgh, PA
Mr. E. L. Von Rosenberg, Exxon Production Research Company, Houston, TX

PROJECT NO: SR-1284
PROJECT TITLE: LIQUID SLOSH LOADING IN CARGO TANKS
INVESTIGATOR: Prof. N. A. Hamlin
CONTRACTOR: Webb Institute of Naval Architecture, Glen Cove, NY
ACTIVATION DATE: August 15, 1982
CONTRACT FUNDING: $111,582 (Two-year project)
SSC LONG-RANGE GOAL: Loads Criteria
CONTRACT NUMBER: DTCG-23-82-C-20016

OBJECTIVE

The objective of this study is to determine sloshing loads on the boundaries, swash bulkheads and internal framing of partially filled tanks of various proportions for liquids of specific gravities ranging from 0.4 to 1.8 and typical enroute service viscosities.

STATUS

A compilation of sloshing forces data on internal tank structures indicates that they might be considered a combination of periodic pressure-related (i.e., inertial) and viscous-related (i.e., drag) components. A simplified mathematical model, which is being developed to approximate liquid velocities in a tank when sloshing occurs, has shown the need to relate the forces experienced by internal structure to tank damping. Plans for constructing and instrumenting the tank models are underway. Tests will be run with models having the flanges on the structural webs, and with pressure transducers on the top of the model tank to measure possible impact pressures.

PROJECT ADVISORY COMMITTEE

Mr. C. W. Coward, Chairman, Newport News Shipbuilding and Dry Dock Company, Newport News, VA
Prof. R. F. Beck, University of Michigan, Ann Arbor, MI
Dr. J. P. Hackett, Ingalls Shipbuilding, Pascagoula, MS

PROJECT NO:	SR-1287
PROJECT TITLE:	JOINT OCCURRENCE OF ENVIRONMENTAL DISTURBANCES
INVESTIGATOR:	Mrs. S.L. Bales
CONTRACTOR:	David Taylor Naval Ship Research and Development Center, Carderock, MD
ACTIVATION DATE:	November 30, 1981
CONTRACT FUNDING:	$75,000 + $20,000 Navy supplement
SSC LONG-RANGE GOAL:	Loads Criteria
CONTRACT NUMBER:	MIPR-Z 70099-2-00919

OBJECTIVE

The objective is to develop a method and a representative data bank, useful for design, that identifies the simultaneous occurrence of winds and directional wave spectra.

STATUS

The specific needs for directional spectra and joint wind/wave statistics, developed from a survey, included, but were not limited to, ship and platform designs, ship routing and weather operability criteria, weapons and aircraft operational design criteria, ship mooring analysis, and marine accident investigation. Present wind/wave modeling techniques lack sufficient measured data for verification, directional spectra or current data, lack a wind spectral model, and must rely on the questionable accuracy of observations on board ships. An approach has been developed to construct frequency-of-occurrence statistics that facilitate selecting a reasonable marine design value and help in making fatigue considerations.

PROJECT ADVISORY COMMITTEE

Prof. M. K. Ochi, Chairman, University of Florida, Gainesville, FL
Dr. D. Hoffman, Hoffman Maritime Consultants, Glen Head, NY
Dr. O. H. Oakley, Jr., Gulf Research & Development Company, Houston, TX
Mr. David Price, National Ocean and Atmospheric Administration, Rockville, MD

PROJECT NO: SR-1288
PROJECT TITLE: FRACTURE CONTROL FOR FIXED OFFSHORE STRUCTURES
INVESTIGATOR: Dr. Jerrell M. Thomas
CONTRACTOR: Failure Analysis Associates
ACTIVATION DATE: April 5, 1982
CONTRACT FUNDING: $56,482
SSC LONG-RANGE GOAL: Materials Criteria
CONTRACT NUMBER: DTCG23-82-C-20015

OBJECTIVE

The objective of this study is to examine critically the technology and practices that constitute the fracture-control plans used by designers, builders, and operators of fixed offshore structures.

STATUS

A written summary of current practices and trends in fracture control is complete. It has seven sections including a general introduction, scope of the fracture-control problems, current practices in material selection, design, construction, and operation and inspection, and ends with a comparison of current practices in the Gulf of Mexico with those in the North Sea. Elements drawn from this summary and a rationale that will be representative of the efforts currently being made by industry will be placed into an integrated framework. Simultaneous efforts are also being devoted to identifying cost-effective components and areas for further research.

PROJECT ADVISORY COMMITTEE

Mr. D. A. Sarno, Chairman, ARMCO Inc., Middletown, OH
Dr. J. D. Burke, Shell Oil Company, Houston, TX
Prof. S. T. Rolfe, Univ. of Kansas, Lawrence, KS
Dr. C. P. Royer, Exxon Production Research Company, Houston, TX
Dr. A. K. Shoemaker, U.S. Steel Corporation, Monroeville, PA

PROJECT NO:	SR-1289
PROJECT TITLE:	STRUCTURAL INSPECTION GUIDELINES
INVESTIGATOR:	Mr. N. S. Basar
CONTRACTOR:	M. Rosenblatt & Son, Inc., New York, NY
ACTIVATION DATE:	September 30, 1981
CONTRACT FUNDING:	$50,878
SSC LONG-RANGE GOAL:	Determination of Failure Criteria (Reliability)
CONTRACT NUMBER:	DTCG 23-81-C-20036

OBJECTIVE

The objective of this study is to develop a guide that will set forth a coherent philosophy toward structural inspection for marine people involved in designing, building, accepting, and operating ships.

STATUS

A thorough review of relevant literature as well as surveys involving 10 ship yards and 14 ships of various types have been completed. The guide will be for people who do ship structural inspections but who do not necessarily have a naval architectural background. It will cover factors affecting the structural integrity of a ship and will suggest that in-service inspectors be aware of potential problem areas disclosed by flaking paint, weeping, and buckling, for example. Photographs of items to be flagged will also be included.

PROJECT ADVISORY COMMITTEE

Mr. C. B. Walburn, Chairman, Bethlehem Steel Corp., Sparrows Point, MD
Dr. C. M. Fortunko, National Bureau of Standards, Boulder, CO
Mr. P. W. Marshall, Shell Oil Company, Houston, TX

PROJECT NO:	SR-1290
PROJECT TITLE:	SHIP FRACTURE MECHANISMS INVESTIGATION
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	3500 man-hours (three-year project)
SSC LONG-RANGE GOAL:	Materials Criteria
CONTRACT NUMBER:	RFP (DTCG23-82-R-20016)

OBJECTIVE

The objectives of this study are to examine current and future ship fractures over a period of years, to examine past ship fractures in the light of present understanding, and to catalog and assess the types of fractures that occur in ship structures.

STATUS

Proposals have been evaluated and contract negotiations are underway.

PROJECT ADVISORY COMMITTEE

Dr. E. J. Ripling, Chairman, Materials Research Lab, Inc., Glenwood, IL
Dr. Richard Bicicchi, Sun Refinery and Marketing Company, Marcus Hook, PA
Dr. C. M. Fortunko, National Bureau of Standards, Boulder, CO

PROJECT NO: SR-1291
PROJECT TITLE: ICE LOADS AND SHIP RESPONSE TO ICE
INVESTIGATOR: Mr. J. W. St. John
CONTRACTOR: ARCTEC, Incorporated, Columbia, MD
ACTIVATION DATE: May 12, 1982
CONTRACT FUNDING: $238,250 (three-year project)
SSC LONG-RANGE GOAL: Response Criteria
CONTRACT NUMBER: (MA-81-SAC-10023)

OBJECTIVE

The objective of this project is to measure ice pressure through the measurement of structural deflections of selected portions of the hull plating on the U.S. Coast Guard icebreaker POLAR SEA to develop ice load and response criteria for various types of ice.

STATUS

A 60-channel digital data acquisition system has been developed, implemented and tested. It is capable of measuring ice loads on a 12-meter (m) square panel in the bow region of the POLAR SEA. The system has a spatial resolution of 0.16 meter squared and a temporal resolution of 0.03 seconds. Tests during the summer deployment were conducted in multi-year ice with thicknesses ranging from 3 m to 15 m, and with single panel pressures reaching 1600 psi. A finite-element program is being developed to simulate the loading and to obtain pressures theoretically.

PROJECT ADVISORY COMMITTEE

Dr. J. E. Goldberg, Chairman, National Science Foundation, Washington, DC
Prof. C. B. Brown, University of Washington, Seattle, WA
Dr. J. G. Giannotti, Giannotti & Associates, Inc., Annapolis, MD
Prof. J. P. Murtha, University of Illinois, Urbana, IL

PROJECT NO:	SR-1292
PROJECT TITLE:	SHIP STRUCTURAL DETAIL DESIGN GUIDE
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	2000 man-hours
SSC LONG-RANGE GOAL:	Design methods
CONTRACT NUMBER:	RFP(DTCG23-81-R-20015)

OBJECTIVE

The objective of this study is to develop a design guide for structural details that will assist designers in the selection of sound, cost-effective details.

STATUS

Proposals have been evaluated and contract negotiations are underway.

PROJECTS ADVISORY COMMITTEE

To be appointed

PROJECT NO: SR-1293
PROJECT TITLE: GUIDE FOR SHIPBORAD VIBRATION CONTROL
INVESTIGATOR: Unknown
CONTRACTOR: Unknown
ACTIVATION DATE: Unknown
CONTRACT FUNDING: 1000 man-hours
SSC LONG-RANGE GOAL: Response Criteria
CONTRACT NUMBER: RFP (DTCG23-82-R-20014)

OBJECTIVE

The objective of this project is to develop a vibration-control guide which will serve as a useful tool in the hands of ship operators, shipyards, and others who must deal with ship-vibration problems but who have limited knowledge and experience in the field.

STATUS

Proposals have been evaluated and contract negotiations are underway.

SHIP-VIBRATION-RELATED PROJECTS ADVISORY COMMITTEE

Dr. B. L. Silverstein, Acting Chairman, Daedalian Associates, Woodbine, MD
Mr. R. A. Babcock, General Dynamics, Quincy, MA
Dr. E. Buchmann, Consultant, Atlanta, GA

PROJECT NO:	SR-1294
PROJECT TITLE:	CALCULATION AIDS FOR PREDICTING GROUNDED SHIP RESPONSES
INVESTIGATOR:	Mr. J. D. Porricelli
CONTRACTOR:	Engineering Computer Optecnomics, Inc., Annapolis, MD
ACTIVATION DATE:	September 30, 1982
CONTRACT FUNDING:	$92,815
SSC LONG-RANGE GOAL:	Loads Criteria
CONTRACT NUMBER:	DTCG23-82-C-20058

OBJECTIVE

The objective of this project is the development of specifications for calculation aids for the assessment of damage, stability, and survivability of grounded vessels.

STATUS

Current literature has been reviewed and a number of grounding and stranding scenarios are being formulated. Portable and ship board loading calculator capabilities are also being examined. Preliminary results indicate that a paucity of information exists aboard ship for input, especially for tramp ships. Analytical techniques are being developed that show good promise of success with only a minimum number of assumptions. Interviews with marine salvage organizations is delayed until more information is available.

PROJECT ADVISORY COMMITTEE

Prof. R. G. Davis, Chairman, Texas A&M University, Galveston, TX
Mr. R. Frederick, SMIT American Salvage, Inc., New York, NY
Mr. R. V. Danielson, Timonium, MD
CAPT H. J. Spicer, Mobil Shipping and Transportation, New York, NY

PROJECT NO: SR-1295
PROJECT TITLE: FULL-SCALE SLAM INSTRUMENTATION AND WAVEMETER DATA COLLECTION
INVESTIGATOR: Unknown
CONTRACTOR: Unknown
ACTIVATION DATE: Unknown
CONTRACT FUNDING: 5000 man-hours (three-year period)
SSC LONG-RANGE GOAL: Loads Criteria
CONTRACT NUMBER: RFP(DTCG23-82-R-20017)

OBJECTIVE

The objective of this project is to instrument a particular vessel with the intent to correlate the recorded slam data with model and analytical predictions for this particular vessel.

STATUS

Proposals have been evaluated and contract negotiations are underway.

PROJECT ADVISORY COMMITTEE

To be appointed.

PROJECT NO:	SR-1297
PROJECT TITLE:	FATIGUE PREDICTION ANALYSIS VALIDATION FROM THE SL-7 HATCH-CORNER STRAIN DATA
INVESTIGATOR:	Drs. Y. K. Chen and J. W. Chiou
CONTRACTOR:	American Bureau of Shipping, New York, NY
ACTIVATION DATE:	August 1, 1982
CONTRACT FUNDING:	$50,000
SSC LONG-RANGE GOAL:	Design Methods
CONTRACT NUMBER:	ABS Funded Separately

OBJECTIVE

The objective of this project is to compare SL-7 hatch-corner fatigue cracking experience with theoretical fatigue calculations.

STATUS

While reviewing the history of the SL-7 containerships' hatch-corner cracking incidents, all the ABS finite-element analyses of the SL-7 containerships were retrieved. These analyses are now being reorganized and summarized. Twenty-six hundred strain-gage data intervals have been selected to produce power spectra. A fatigue histogram will then be constructed in a manner analogous to the "long-term" analysis or by simulation followed by fatigue cycle counts.

PROJECT ADVISORY COMMITTEE

Mr. J. E. Steele, Chairman, Quakertown, PA
Mr. J. W. Boylston, Giannotti & Associates, Inc., Annapolis, MD
Prof. H. W. Liu, Syracuse University, Syracuse, NY
Prof. W. H. Munse, University of Illinois, Urbana, IL

PROJECT NO:	SR-1298
PROJECT TITLE:	FATIGUE CHARACTERIZATION OF SHIP DETAILS -- PHASE II
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	3000 man-hours over two years
SSC LONG-RANGE GOAL:	Materials Criteria
CONTRACT NUMBER:	Unknown

OBJECTIVE

The objective of this project is to examine, analyze, and test more structual details and determine their influence on fatigue, which will ultimately lead to analytical procedures to evaluate and select fabricated ship details.

STATUS

A proposal request is being prepared.

PROJECT ADVISORY COMMITTEE

To be appointed.

PROJECT NO: SR-1299
PROJECT TITLE: DESIGN-INSPECTION-REDUNDANCY SYMPOSIUM/WORKSHOP
INVESTIGATOR: SR-1299 Steering Committee
CONTRACTOR: National Academy of Sciences, Washington, DC
ACTIVATION DATE: July 1, 1982
CONTRACT FUNDING: $40,000 - two years
SSC LONG-RANGE GOAL: Advanced Concepts and Long-Range Planning
CONTRACT NUMBER: ABS Grant

OBJECTIVE

The objectives of this symposium/workshop are to examine the emerging technologies of ultimate strength and failure mode analyses as applicable to marine structure systems, to delineate the most pressing problems, and to develop a detailed work plan.

STATUS

A three-day symposium followed by a two-day workshop will be held in Williamsburg, Va., November 14 thru 18, 1983. Session chairmen have been appointed, authors have accepted, and a program has been developed. Preprints, proceedings, and a summary with the detailed work plan will be developed.

STEERING COMMITTEE

Prof. A. H.-S. Ang, Chairman, University of Illinois, Urbana, IL
Prof. Douglas Faulkner, The University of Glasgow, Glasgow, Scotland
Mr. P. W. Marshall, Shell Oil Company, Houston, TX
Prof. Robert Plunkett, University of Minnesota, Minneapolis, MN
Prof. Masanobu Shinozuka, Columbia University, New York, NY

PROJECT NO:	SR-1300
PROJECT TITLE:	DEVELOPMENT OF A GENERALIZED ONBOARD RESPONSE MONITORING SYSTEM
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	3500 man-hours over 2.5 years. SNAME contributing $10,000.
SSC LONG-RANGE GOAL:	Response Criteria
CONTRACT NUMBER:	Unknown

OBJECTIVE

The objectives of this project are to develop a generalized operations-oriented stress and motion monitoring system, and implement it onboard three different types of vessels.

STATUS

SNAME's HS-12 Panel on Instrumentation has completed Tasks 1 and 2 of Phase I as proposed last year. The panel has now rewritten the work scope and has submitted it to the Committee on Marine Structures for review.

PROJECT ADVISORY COMMITTEE

To be appointed.

REVIEW OF COMPLETED PROJECTS

The projects completed since the last annual report are listed below. Project descriptions similar to those for the active program follow. Reports from these projects have either been published or are at present in publication. The final SSC reports can be expected in the near future and will be available from the National Technical Information Service, Springfield, Virginia 22314.

SR-1270, "Survey of Experience Using Reinforced Concrete in Floating Marine Structures"

SR-1280, "Analysis and Assessment of Major Uncertainties in Ship Hull Design"

SR-1281, "Ship Structures Loading in Extreme Waves"

SR-1282, "In-Service Still-Water Bending Moment Determination"

SR-1285, "Determination of the Range of Shipboard Strain Rates"

SR-1286, "Fillet Weld Strength Parameters for Shipbuilding"

SR-1296, "Long-Range Research Plan Review"

PROJECT NO.: SR-1270
PROJECT TITLE: SURVEY OF EXPERIENCE USING REINFORCED CONCRETE IN FLOATING MARINE STRUCTURES
INVESTIGATOR: Dr. O. H. Burnside
CONTRACTOR: Southwest Research Institute, San Antonio, TX
ACTIVATION DATE: November 26, 1979
CONTRACT FUNDING: $41,252
SSC LONG-RANGE GOAL: Advanced Concepts and Long-Range Planning
CONTRACT NUMBER: DOT-CG-919837-A

OBJECTIVE

The objective of this project was to assess the state of the art for reinforced concrete, including prestressed and conventionally reinforced concrete, applicable to floating marine structures.

RESULTS

A draft final report has been reviewed and is being revised for publication. It includes sections on a literature and industry survey; the uses of reinforced concrete in marine structures, including application, design concepts, and experience with various concrete materials; the identification of the material properties and how they are incorporated into actual design; a schedule of research studies; and an extensive bibliography. The authors conclude: a) current construction techniques appear adequate when deadweight/displacement ratio is not a concern, and b) current design procedures following existing codes satisfy service requirements.

PROJECT ADVISORY COMMITTEE

Dr. J. E. Goldberg, Chairman, National Science Foundation, Washington, DC
Prof. Z. P. Bazant, Northwestern Univ., Evanston, IL
Prof. J. E. Breen, University of Texas, Austin, TX
Prof. N. M. Hawkins, University of Washington, Seattle, WA
Dr. B. J. Watt, Brian Watt Associates, Inc., Houston, TX

AD-A126 893 REVIEW AND RECOMMENDATIONS FOR THE INTERAGENCY SHIP STRUCTURE COMMITTEE'S..(U) NATIONAL RESEARCH COUNCIL WASHINGTON DC MARINE BOARD A D HAFF ET AL. 1983

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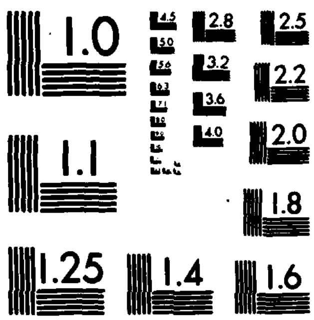


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

[illegible]

Contract Number: [illegible]

Objective

The objective of the study was to identify the major sources of uncertainties underlying the design of ship hull structures.

Results

A draft final report has been reviewed. It is a summary taken from existing literature. Although the introduction states "different uncertainties are taken into account by introducing probability concepts into the structural design procedure," no design procedure is recommended. Among the authors' findings are: (a) a more firm value of the coefficient of variation (COV) for wave loads due to statistical variability of the wave spectrum; (b) an estimate of the error of theoretical calculation capability for determining bending moment [illegible] was found to be a COV of [illegible] percent; c) the [illegible] [illegible]

[illegible]

[illegible]

OBJECTIVE

The objective of the study was to examine the possibility of a ship encountering some kinds of extreme waves and to understand the significance of this in ship structural design.

STATUS

A draft final report has been reviewed. It is provocative in that it challenges accepted concepts on the use of Gaussian random-wave representations for the design of marine structures. Theoretical and experimental support is presented for the existence and stability of long-crested, non-dispersive, steep and elevated waves. This suggests that the use of design waves for extreme overload analysis of marine structures is more than just an extended tradition. The report states that design which would appear to require [illegible]

[illegible]

[illegible]

[illegible]

[illegible] COMMITTEE ON MARINE STRUCTURES

9. Performing Organization Name and Address

NATIONAL ACADEMY OF SCIENCES
2101 CONSTITUTION AVENUE
WASHINGTON, D.C. 20418

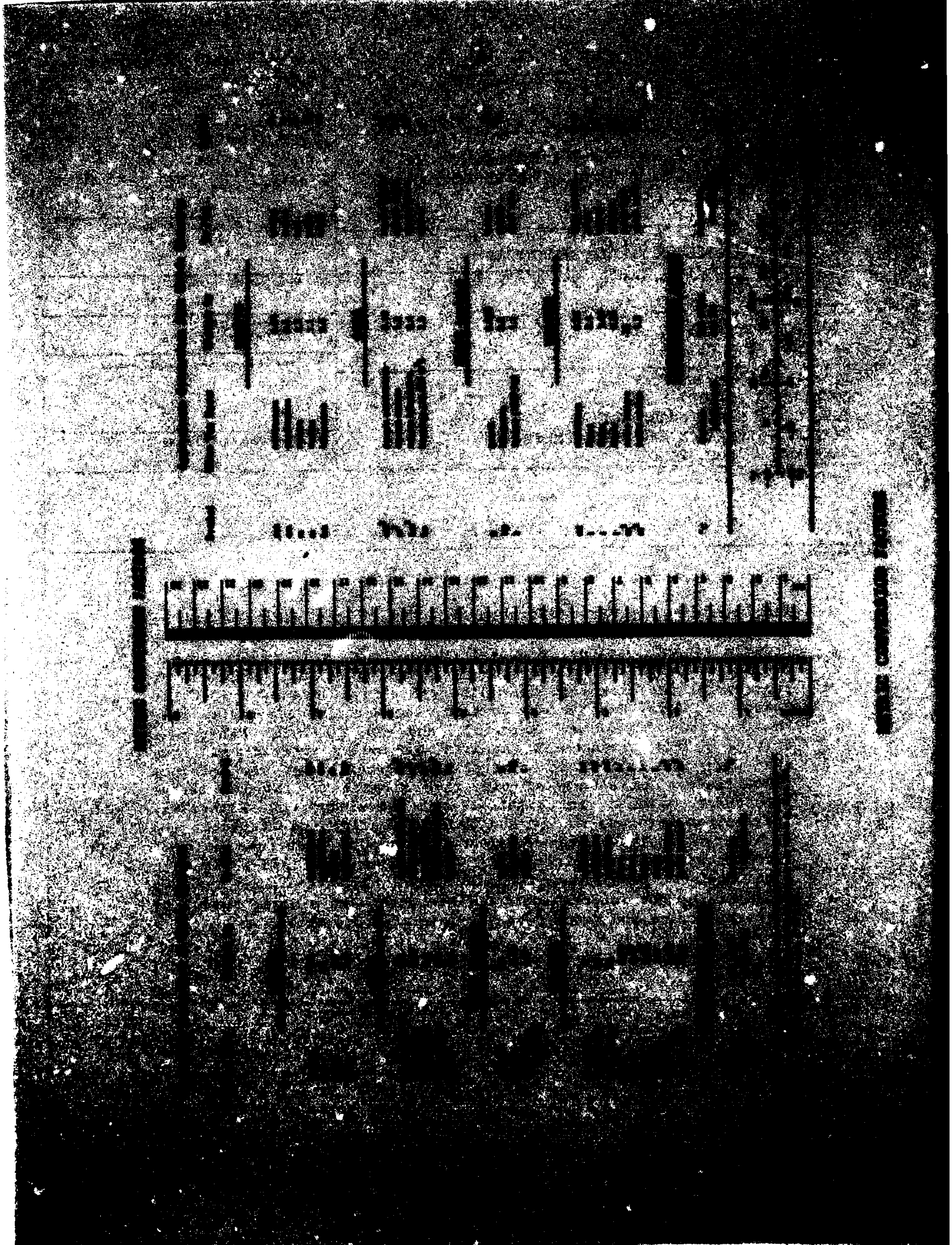
12. Sponsoring Agency Name and Address

COMMANDANT (G-DST)
U.S. COAST GUARD HEADQUARTERS
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D.C. 20590

15. Supplementary Notes

16. Abstract

The Committee on Marine Structures (CMS) of the Marine Board of the National Research Council provides technical advisory [illegible]



THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 900 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official - yet independent - advisor to the federal government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the government.

THE NATIONAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date, the Council of the National Academy of Sciences, under the Authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the federal government, upon request, on any subject of science or technology.

THE NATIONAL RESEARCH COUNCIL was established in 1916, at the request of President Woodrow Wilson, by the National Academy of Sciences to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy by authority of its Congressional charter of 1863, which establishes the Academy as a private, non-profit, self-governing membership corporation. Administered jointly by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine (all three of which operate under the charter of the National Academy of Sciences), the Council is their principal agency for the conduct of their services to the government, the public, and the scientific and engineering communities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

THE COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS is one of the major components of the National Research Council and has general responsibility for and cognizance over those program areas concerned with the development and application of the engineering disciplines to technological and industrial systems, and their relationship to problems of both national and international significance.

THE MARINE BOARD is an operating unit of the Commission on Engineering and Technical Systems of the National Research Council. The Board addresses issues of current and continuing importance to the government and the nation in ocean resources and maritime transporation development; coastal, port and harbor, and inland waterway use; support of science; and national and international cooperation and information exchange.

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